Cairo Air Improvement Project

Vehicle Emissions Testing Component

Data Analysis Report for the On Road Testing (ORT) Program

Chemonics International, Inc.

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EXECUTIVE SUMMARY

1.1 Background

EEAA, the Ministry of the Interior (MOI), USAID, and CAIP initiated an on-road-testing (ORT) program designed to help plan for upcoming vehicle emissions testing (VET) and tune-up activities and to be used as a public awareness campaign. Between 7 February 1999 and the present, over 35,000 vehicles have been tested in the ORT program. This report analyzes the results of approximately the first 25,000 vehicles tested.

Testing was conducted jointly by MOI and EEAA with support provided by CAIP. Eighteen test sites were established. A QA/QC program was established to ensure the quality of data gathering and data processing activities of ORT.

1.2 Vehicle Population

The results of testing 22,083 gasoline-powered and 3,176 diesel-powered vehicles were analyzed. The number of vehicles tested varied by location, from 55 at El-Sarayat Traffic Department to 2,767 at the Giza Traffic Department. Vehicle model years were clustered into two predominant groups, from about 1973 to 1984 and from 1994 to 1999, resulting from favorable import and pricing policies and increased local production capacity.

The largest categories of gasoline-powered vehicles were passenger vehicles and taxis. The largest categories of diesel-powered vehicles were trucks and taxis. Fiat, Peugeot, and Nasr represented nearly half the gasoline vehicles tested, and Chevrolet and Toyota dominated the diesel-powered vehicle category.

1.3 Emissions Test Results

Failure rates for gasoline-powered vehicles ranged between 31% and 39%. Diesel failure rates were from 1% to 2%. Twenty percent of the gasoline-powered vehicles accounted for 50% to 53% of the hydrocarbon emissions and 38 to 49% of the carbon monoxide emissions. Twenty percent of the diesel-powered vehicles accounted for 40% to 42% of the smoke (opacity) emissions.

1.4 Conclusions

The following are significant conclusions reached after studying the results of the on-road-testing and subsequent data analysis:

- Certain makes and types of vehicle are dominant
- Overall non-compliance rates for gasoline-powered vehicles are between 31% and 39%
- Overall non-compliance rates for diesel-powered vehicles are between 1% and 2%

- If enforced, the HC standards for gasoline-powered vehicles would result in approximate reductions in HC of 56% for pre-1995 vehicles and 30% for 1995 and after

- If enforced, the CO standards for gasoline-powered vehicles would result in approximate reductions of 45% for pre-1995 vehicles and 69% for 1995 and after

- If enforced, the opacity standards for diesel-powered vehicles would result in approximate reduction of only 5-6% for the entire vehicle population tested

1.5 Recommendations

The following are recommendations to address some of the limitations of the ORT program:

- Develop a procedure that guarantees random testing of cars

- Enhance the current level of QA/QC for all parts of the program

- Set future standards based on desired reductions in pollutant levels.

- Compare the data gathered in the ORT program with that gathered in the vehicle emission testing (VET) program.

- Investigate remote sensing technology

1.6 Next Steps

The following are the suggested next steps in the ORT program:

- Train EEAA personnel to take over the ORT program

- Train EEAA personnel in the use of the database.

- Investigate the use of data loggers to reduce data entry errors

- Investigate the use of computerized scanners to read license information

SECTION 2
BACKGROUND

2.1 Introduction

On-road emissions' testing of automobiles was conducted in various locations in Cairo over the period from 7 February 1999 until the present. On-road testing will continue indefinitely or until the Ministry of the Environment decides otherwise. This report contains a summary and analysis of the test results for approximately the first 25,000 vehicles tested. This section summarizes the background and methodology of the program. Subsequent sections describe the vehicle population and emissions levels based on the tests performed.

2.2 Background, Goals, and Objectives

EEAA and the Ministry of Interior share in the ultimate goal of reducing vehicle emissions and increasing fuel efficiency in Greater Cairo. EEAA and the Ministry of Interior decided to sample a representative group of vehicles and take a initial step towards that goal.

The ORT program is being used as a public awareness campaign to educate the motorists regarding the effect of emissions on the public health, the upcoming vehicle emissions testing (VET) program, the benefits of emission-based tune-ups, and repair facilities where tune-ups can be done.
Additionally, the results of the ORT effort will be useful to help plan for the upcoming testing and tune-up program and for guiding discussions that may be required future modifications of the standards in Law 4.

The on-road testing (ORT) program is the result of a number of discussions between EEAA, the Ministry of Interior, USAID, and CAIP. The program is implemented jointly by EEAA and the Ministry of Interior with technical assistance and equipment support from CAIP.

2.3 Legal Context

The program is based on existing traffic and environmental laws. Traffic Law No. 66 provides the authority to enforce both safety and exhaust requirements on vehicles operating on public roadways. The following are applicable portions of Law 66:

<u>Article 33:</u> Authorizes the Traffic Police to stop any vehicle that does not meet prescribed technical safety conditions, move the vehicle to the nearest traffic department and undertake a full technical inspection of the vehicle. Should the vehicle be found in violation of the requirements, the license plate as well as the motorist's driving license can be seized.

Article 72: Provides that the license can be held for a period not less than 30 days and not more than 60 days or the remaining period for which the license is valid, whichever is less. in the following cases:

1. If the vehicle is dropping any of its load; or
2. If it is leaking any matter that is deemed hazardous to the public health or detrimental to the road or its users.

Article 74: Indicates that a motorist can be fined an amount not less than LE 5 and not more than LE 25 if the vehicle is "...making any unusual sounds, emitting dense smoke, bad smell, flammable or health hazardous material."

Law 4 establishes emissions limits for vehicles. Article 37 of Executive Decree No. 338, year 1995, of Law 4 contains the limits for pollutants shown in Table 2.1 below.

Table 2.1. Limits for Pollutants as Presented in Article 37

Fuel Type	Pollutant	Before 1995	1995-1999
Gasoline	CO	7%	4.5%
Gasoline	HC	1,000 PPM	900 PPM
Diesel	Opacity	65%	50%

2.4 Program Organization

The ORT program includes 30 EEAA staff. There are 18 field teams, one at each test location, plus a supervisory team of three EEAA personnel. Each field team consists of:

1. Traffic Officers – People knowledgeable in the requirements of the traffic laws and who are authorized to stop, inspect, and cite vehicles and operators as required. At any given location the number of Traffic Officers varies, depending on the particular Traffic Department assignments made.

2. EEAA Inspectors – People trained in the operation and calibration of the exhaust testing equipment (exhaust gas analyzer and opacity meter). Inspectors also collect data during field exercises and provide public awareness materials to the motorists. There is one EEAA Inspector per monitoring instrument, therefore, at sites where only gasoline-powered vehicles or diesel-powered vehicles are tested, there is only one EEAA Inspector. At sites where both gasoline-powered and diesel-powered vehicles are tested, there are two EEAA Inspectors.

CAIP personnel coordinate the activities of the ORT teams, perform QA/QC, coordinate equipment maintenance, buy spare parts, perform public awareness activities, dispense public awareness materials, and receive the data from the inspection teams to process and analyze.

2.5 Test Locations

Table 2.2 is a summary of the eighteen- (18) testing locations, and Figure 2.1 is a map showing the locations. The Ministry of Interior chose the test locations; eight were placed on the main access roads to Cairo, and the rest were located at various Traffic Department locations. Of the 18 locations, seven tested vehicles with both diesel and gasoline engines, one tested only diesel vehicles, and ten tested only gasoline vehicles.

Table 2.2. Test Site Locations

No.	Site Designation	Engine Fuel Type	
1	Cairo-Alexandria Agricultural Road	Diesel	Gasoline
2	Cairo-Alexandria Desert Road	Diesel	Gasoline
3	Cairo-Suez Desert Road	Diesel	Gasoline
4	Cairo-El Fayoum Desert Road	Diesel	Gasoline
5	Cairo-Ismailia Desert Road	Diesel	Gasoline
6	Cairo-Bilbeis Desert Road		Gasoline
7	Cairo-El Khatameya Desert Road		Gasoline
8	Shoubra El Kheima Traffic Department	Diesel	Gasoline
9	Shoubra Aboud Traffic Department		Gasoline
10	El-Darassa Traffic Department		Gasoline
11	Banha Traffic Dept.		Gasoline
12	Nasr City Traffic Dept.		Gasoline
13	El-Salam Traffic Dept		Gasoline
14	El-Sarayat Traffic Dept		Gasoline
15	El-Tibbin Traffic Dept.	Diesel	
16	El-Hawamdeya Traffic Dept	Diesel	Gasoline
17	El-Agoza Traffic Dept		Gasoline
18	Nekla Traffic Dept		Gasoline

2.6 Method of Testing

As part of his daily duties, the Traffic Officer selects vehicles randomly and directs them to pull over to the testing location. He verifies the operator's and vehicle's credentials.

As the Traffic Officer performs his duties, the EEAA Inspector explains the purpose of the testing and takes the tailpipe readings using the emissions analyzer (gasoline and diesel vehicles) or the opacity meter (diesel vehicles). He records data on a pre-printed form, a copy of which is shown in Figure 2.2. In addition he provides the drivers with public awareness materials on Law 4 emission standards, the health effects of air pollutants, how drivers can meet Law 4 standards (low emission tune up), and recommendations on where they can have their cars tuned up.

2.7 Timeframe and Working Hours

Actual testing of vehicles began on 7 February 1999 and is continuing. Testing is planned to continue until the Ministry of the Environment decides to discontinue it.

The normal working hours for the EEAA Inspectors are from 8:30 am to 4:00 pm. However, the work of the EEAA inspectors is tied to the hours during which the Traffic Officers work. In the winter, the average working time of a road checkpoint is greater than in the summer. Therefore, during the summer months, the amount of data collected per day is reduced.

The testing program uses a Snap-On Diagnostics Model DGA 1000 Diagnostic Gas Analyzer for HC and CO emissions measurements of gasoline powered vehicles and a Sun Model SSM 2000 Smoke Meter for opacity measurements of diesel powered vehicles.

2.8 Quality Assurance and Quality Control (QA/QC)

The ORT program included a number of activities and measures to ensure the overall quality of the data. The QA/QC program included operator training, equipment checking and maintenance, standardized data collection forms and data entry screens, review of completed data forms, QC checks on entered data, and exploratory data analysis.

2.8.1 Operator Training

All staff assigned to the ORT program went through a classroom and hands-on training session about the goals of the ORT program, operations of the emissions sampling devices, and procedures for completing the data form. The purpose of the training program was to support the EEAA inspectors to fulfill their functions in successful implementation of the ORT program.

The training was comprised of two (2) sub-modules, a general session, and small group training. In the general session, all parties involved were provided with a general understanding of the ORT program, their roles and responsibilities, and the timeframe for program start up and operation.

In the small group training sessions, EEAA inspectors were instructed on using gas analyzers and performing on-road-testing functions. In addition, learned how to communicate with motorists and promote VET public awareness

2.8.2 Equipment Care

All sampling devices were maintained according to the manufacturers' instructions. This maintenance included changing filters on a regular basis and generally checking the devices to ensure they were in good repair. The instruments were initially calibrated by the manufacturers, and the instruments have built-in, self-calibrating features.

2.8.3 Data Forms and Data Entry

The data form that was used for the ORT program was presented in Figure 2.2. This form, in Arabic, was used without changes throughout the sampling period.

Completed data forms were collected when the book in which they were contained was filled. A CAIP staff member familiar with the program inspected the forms before data entry. This staff member checked for missing critical information and unclear notations and spot-checked them for obvious errors to prepare the forms for data entry. Data forms were not sent back to the field because recovery of missing information was not feasible. If non-critical fields were missing, the data forms were entered into the database. Alternatively, if critical fields were missing, they were not entered.

CAIP support staff entered the contents of the data forms in to a Microsoft Access database through customized screens. Pull-down menus were used to minimize errors on critical fields (e.g., vehicle makes).

2.8.4 Error Checking and Exploratory Data Analysis

CAIP analysts performed electronic checks for missing values and values outside the expected range. Examples include opacity values greater than 100 percent and vehicle manufacture years higher than 1999. A subset of approximately 300 electronic records, selected arbitrarily, was also compared with the paper forms. This comparison revealed that some errors could be easily corrected, such as the vehicle RPM value erroneously entered into the opacity value field.

Several exploratory analyses were performed to check the database for possible errors. These analyses included assessments of differences in compliance rates by sampling date and location, and relative contributions of vehicle makes and types in the database versus perceptions from the field.

Only errors that should obviously be another value were changed in the database. A small fraction of the records with missing emissions results was eliminated from the database. Other records with problematic values (e.g., missing vehicle year) were retained for the analyses that did not use the erroneous field.

2.8.5 Assumptions and Data Limitations

The ORT database is now the largest vehicle emissions testing database in Egypt. It allows us to identify overall trends about the general state of certain gasoline and diesel vehicle makes and types.

Several limitations in the data that must be understood before conclusions that are more specific can be drawn or the data are used to support policy making.

1. *The program was not designed to randomly sample vehicles according to a statistically based sampling scheme.* Operators were instructed to stop vehicles "randomly" and the overall sample appears reasonably representative of the vehicle population in Greater Cairo. However, sampling location and vehicle selection biases undoubtedly exist and will affect the results. For example, different locations have different vehicle age, type, and manufacturer profiles. The team also noted that there was at least one clear case of vehicle selection bias by operators—woman-occupied vehicles were selected less frequently than those driven by men.

2. *Exhaust system integrity checks were not performed.* The overall fleet age and other anecdotal evidence suggest that leaks or deliberate system bypasses may exist in some cars..

3. *Only trucks up to four metric tons in overall weight were included.* Heavier vehicles were not included in the program, preventing broader application of the results.

4. *Certain microbuses were excluded for technical reasons.* Approximately five makes of microbuses manufactured in the last several years could not accommodate the RPM sensor and therefore could not be tested. The effect of this situation on the overall diesel results is expected to be small.

5. *Motorcycles are not included in the current analysis.* Motorcycle testing was begun later, and results are included in a separate report.

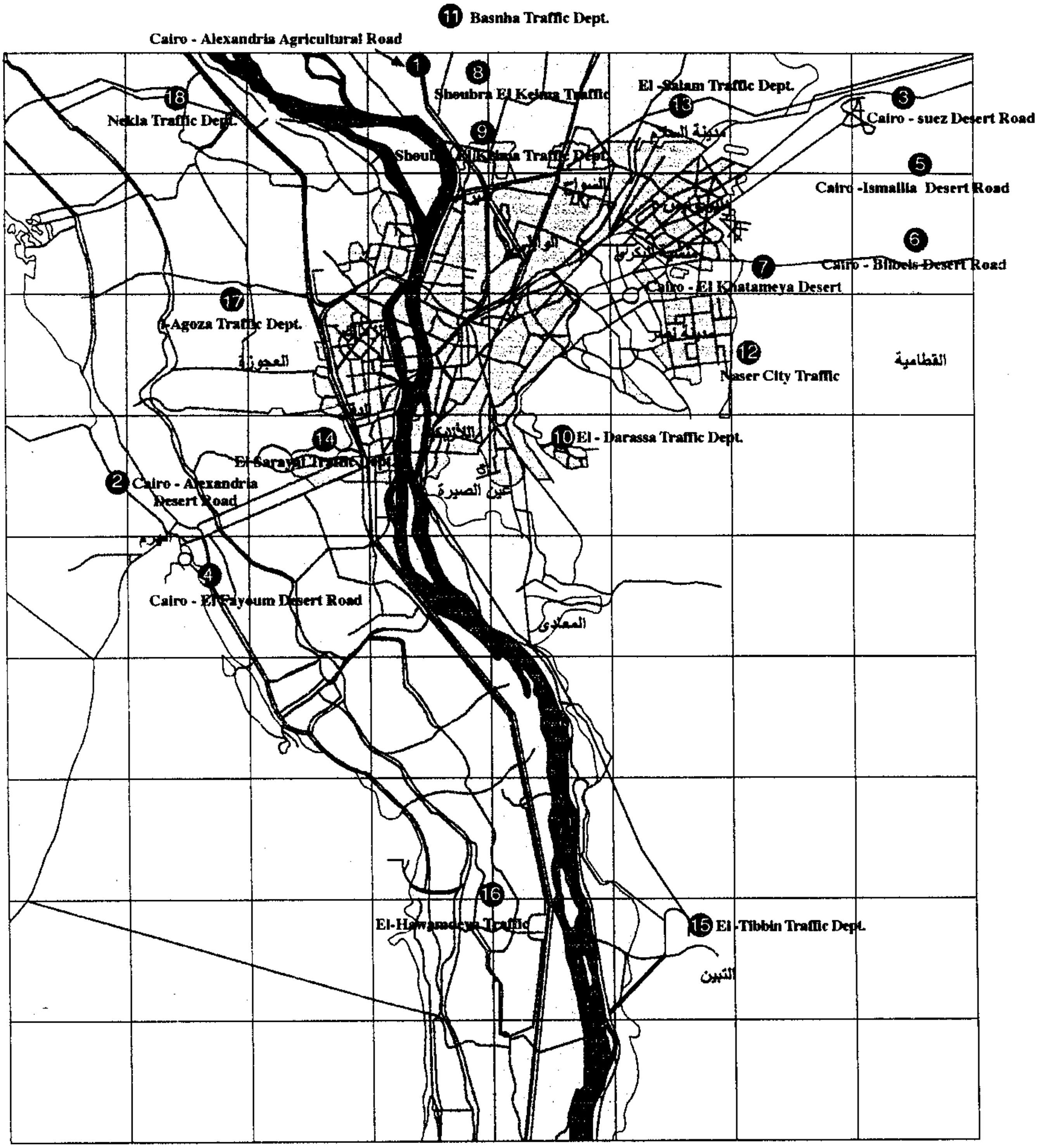


Figure 2.1
ORT Testing Locations

Figure 2.2
Form Used By Inspectors to Record Data

(Serial Number) **EEAA** **General Traffic Authority**

Vehicle Inspection Form

General Information	
Vehicle Plate Number	Test Location
License Type	Licensing Department
Model Year	Vehicle Make

Inspection Results				
Emissions Type	Before 1995		1995 and After	
	Standard	Result	Standard	Result
Hydrocarbons (HC)				
Carbon Monoxide (CO)				
Opacity				

EEAA Inspector
Name
Date

SECTION 3
VEHICLE POPULATION

The following section describes the number of vehicles tested during the reporting period and the fleet profile according to fuel types, model year, government-defined vehicle type, and make.

3.1 Number of Vehicles Tested

During the period from 7 February 1999 to the present, an average of approximately 3,000 vehicles per month was tested. A subset of the total data gathered is analyzed in this report. This subset includes records for 25,259 vehicles, 22,083 (87%) gasoline-powered and 3,176 (13%) diesel-powered.

3.2 Number of Vehicles Tested by Location

Vehicles were tested at two types of locations; on roads leading into and out of the greater Cairo area and at Traffic Departments. Table 3.1 is a summary of the number of vehicles tested by location for gasoline and diesel-powered vehicles. Two entries in the Table require some explanation. Data were erroneously entered into the database for locations at the "Cairo Traffic Department" and the "Giza Traffic Department." These two locations don't exist; there are several Traffic Departments in Giza and several in Cairo. It was decided for the purposes of this report that these records would be kept for analysis because the location at which data were collected doesn't affect any of the subsequent calculations in the report.

The number of vehicles tested per location ranged from 55 at El-Sarayat Traffic Department to 2,767 at the Giza Traffic Department. The total number of vehicles tested at Traffic Departments was 15,702 (62.2%), and the total number tested at on-road locations was 9,557 (27.8% of the total).

Table 3.1 indicates that the largest numbers of gasoline-powered vehicles were tested at the Giza Traffic Department (12.5%), Katameya Road (10.8%), Shoubra (Aboud) Traffic Department (10.6%), Belbeis Desert Road (9.3%), and Nekla Traffic Department (9%). Taken together, these five locations, out of the total 19 locations listed in the Table, accounted for 52% of all gasoline-powered vehicles tested.

The largest numbers of diesel-powered vehicles were tested at Ismailia Road (25.8%), El-Tebbin Traffic Department (18%), Ell-Hawamdeya Traffic Department (16.8%), and Shoubra El-Kheima Traffic Department16%). Taken together, these four locations, out of the total 8 locations listed in the Table, accounted for nearly 77% of all diesel-powered vehicles tested.

3.3 Number of Vehicles Tested by Model Year

Figure 3.1 is a summary of the number of gasoline-powered vehicles, by model year. A breakdown of numbers of gasoline-powered vehicles tested per model year period is shown in Table 3.2.

The figure and table show two large groupings in model years represented in the testing. One grouping is between about 1973 and 1984, and the second grouping is between about 1994 and 1999. The first peak may be attributed to the lifting of tight restrictions on imported cars after the war in 1973 and the response of the public because of a pent-up demand for cars. The second peak may be attributed to the local production of many makes of cars plus significant price reductions.

The majority of the gasoline-powered vehicles tested were in the time periods 1975 to 1984 and 1995 to 1999, representing 10,597and 5,295 vehicles, respectively, or a total of 15,892 (72%% of the total of 22,083). Note that 50 percent of the gasoline-powered vehicles tested are at least sixteen years old.

Figure 3.2 is a summary of the number of diesel-powered vehicles, by model year. A breakdown of numbers of diesel vehicles tested per model year period is shown in Table 3.3.

Like -for gasoline-powered vehicles, the graph for diesel-powered vehicles has two groupings. A similar explanation may be made for the double peaks shown for diesel vehicles. In addition, importation of passenger cars with diesel engines was banned prior to 1979. In 1979 various types of diesel trucks (Chevrolet, Bedford, etc.) began to be imported.

The majority of the diesel-powered vehicles were tested in the time periods 1980 to 1984 and 1990 to 1999, 650 and 1,864 vehicles, respectively, or a total of 2,514 vehicles (79% of the total of 3,176). Note that most of the diesel vehicles tested are relatively new (59% are 1990 and newer vehicles).

3.4 Vehicle Types

Vehicle types, as indicated on the vehicle licenses, include passenger, taxi, truck, bus, commercial, customs, free zone, government, police, public sector, and tourism vehicles. These license types were placed into four vehicle type categories for the purposes of this report; bus/van, passenger, taxi, and truck.

A summary of these vehicle types for both gasoline and diesel-powered vehicles is shown in Table 3.4. Passenger vehicles and taxis dominate the gasoline-powered vehicles that were tested; together they account for 93% of the gasoline-powered vehicles. Trucks and taxis dominate the diesel-powered vehicles; together they account for 95% of the diesel-powered vehicles.

3.5 Vehicle Makes

Figure 3.3 is a summary of the number of gasoline-powered vehicles, by make, and Table 3.5 is a breakdown of those numbers. The top three makes (Fiat, Peugeot, and Nasr) represent nearly half of all gasoline-powered vehicles tested. The top 10 vehicle makes represent 75%, and the top 20 vehicle makes represent 92% of all gasoline-powered vehicles tested.

Figure 3.4 is a similar summary of the makes of diesel-powered vehicles tested. A breakdown of these numbers for diesel vehicles is given in Table 3.6. The top two diesel-powered makes (Chevrolet and Toyota) represent more than half, and the top 10 represent 90% of all diesel vehicles tested.

Figure 3.1
Gasoline Powered Vehicles Tested By Model Year

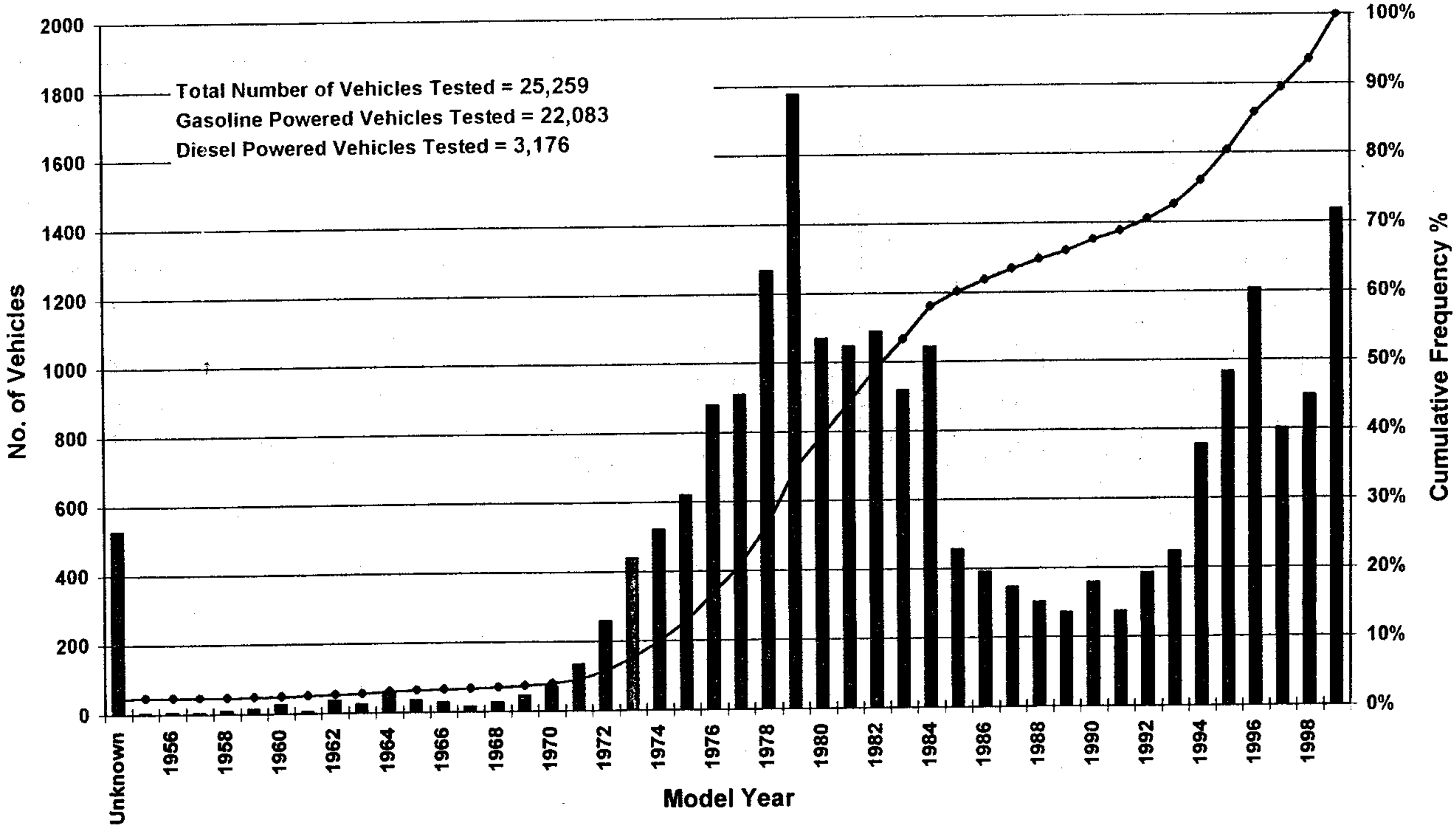


Figure 3.2
Diesel Powered Vehicles Tested by Model Year

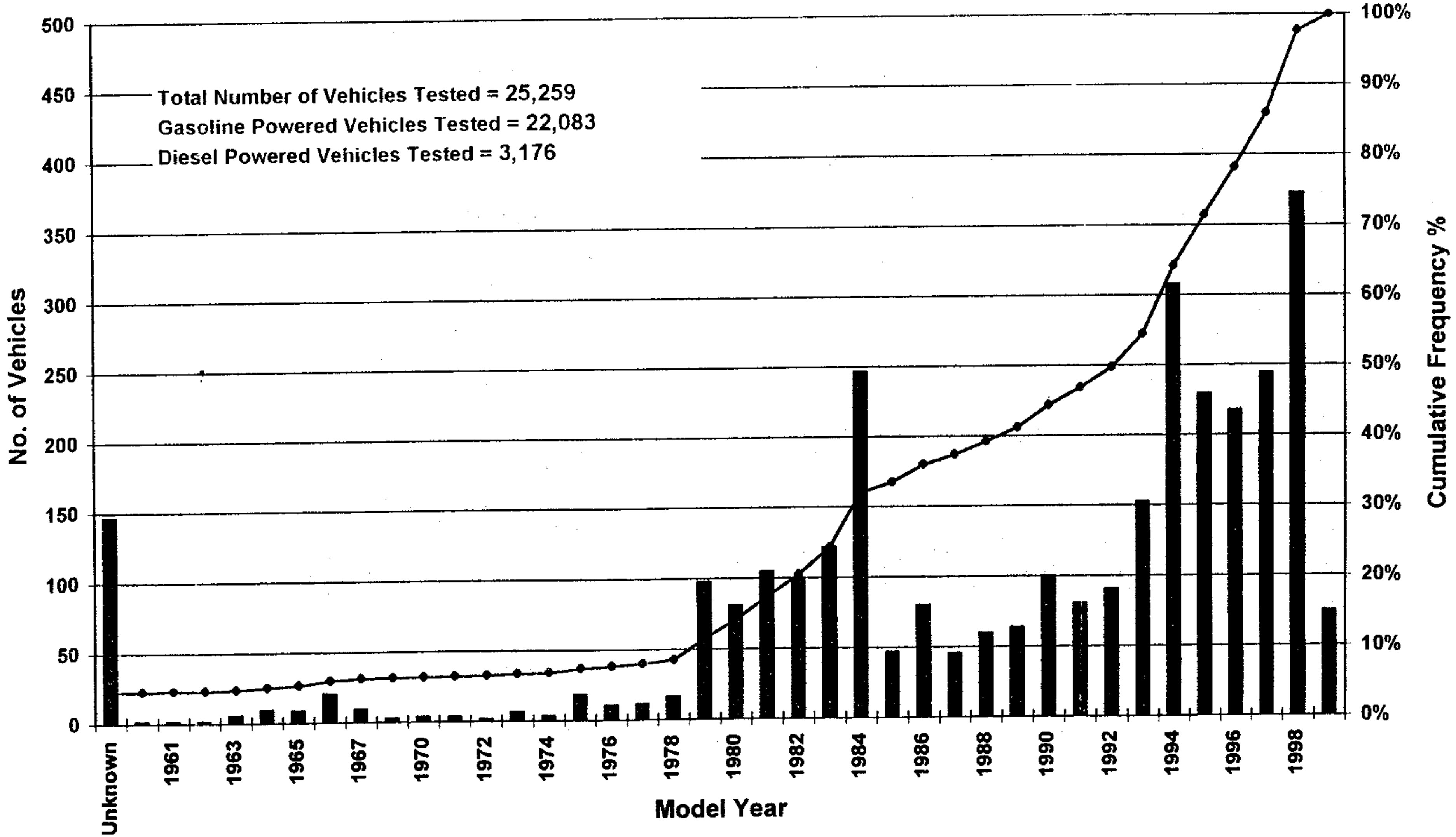


Table 3.2. Gasoline-Powered Vehicles Tested Per Model Year

	Vehicle Manufacture Year							
	Unknown	Before 1970	1970-1974	1975-1979	1980-1984	1985-1989	1990-1994	1995-1999
Number	525	300	1,411	5,442	5,155	1,748	2,207	5,295
Cum. %	2.4	3.7	10.1	34.8	58.1	66.0	76.0	100

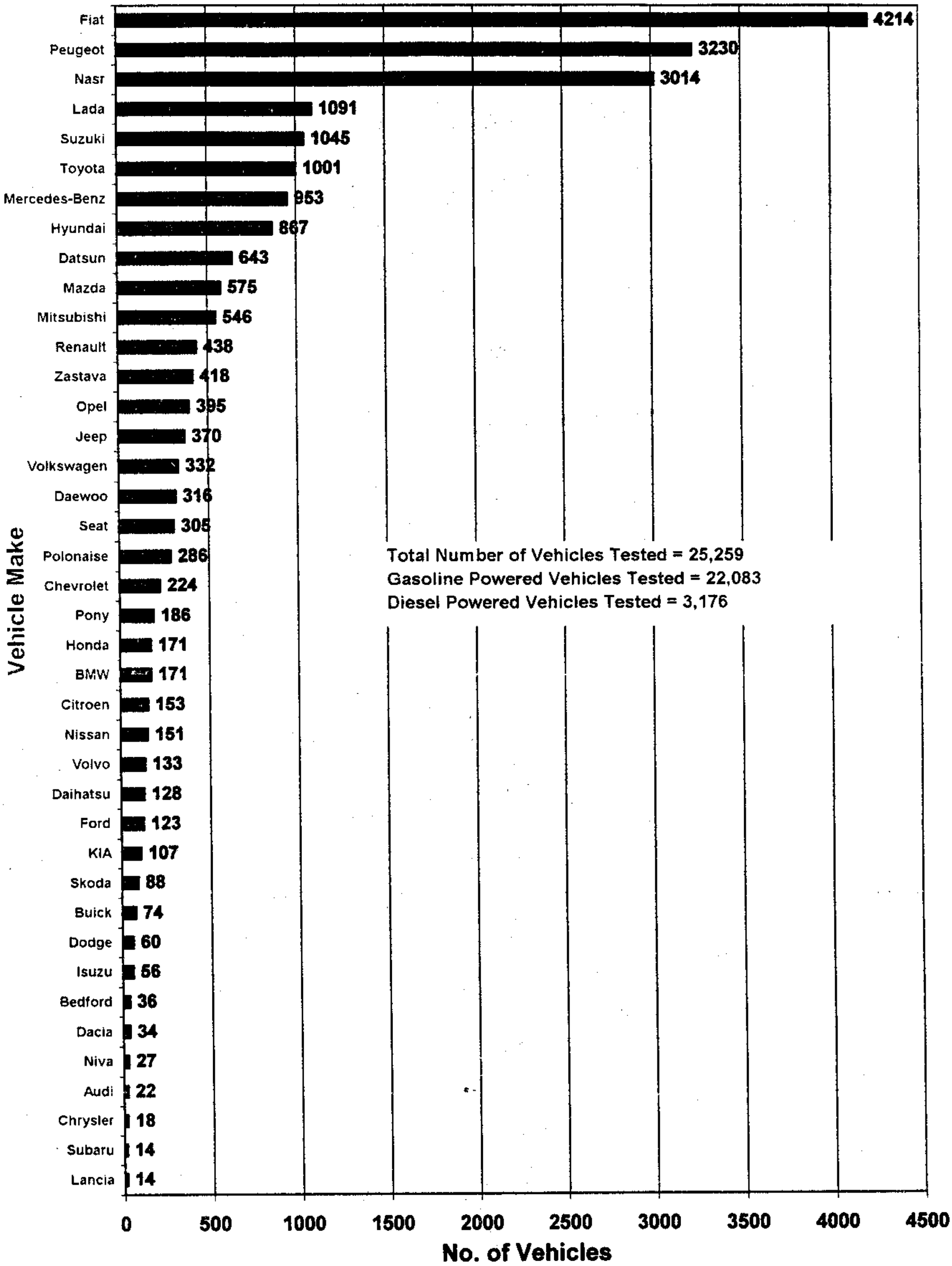
Table 3.3. Diesel-Powered Vehicles Tested per Model Year

	Vehicle Manufacture Year							
	Unknown	Pre-1970	1970-1974	1975-1979	1980-1984	1985-1989	1990-1994	1995-1999
No.	146	56	16	152	650	292	728	1,136
Cum. %	4.6	6.4	6.9	11.6	32.1	41.3	64.2	100

Table 3.4. Summary of Vehicle Types Tested

Vehicle Type	No. of gasoline-powered vehicles tested	Percent of total	No. of diesel-powered vehicles tested	Percent of total	Total Vehicles Tested
Passenger	15,230	69	107	3.4	15,337
Taxi	5,382	24	830	26	6,212
Truck	1,409	6	2,198	69	3,607
Bus/Van	62	0.2	41	1.3	103
Total	22,083	100	3176	100	25,259

Figure 3.3
Gasoline Powered Vehicles Tested by Make



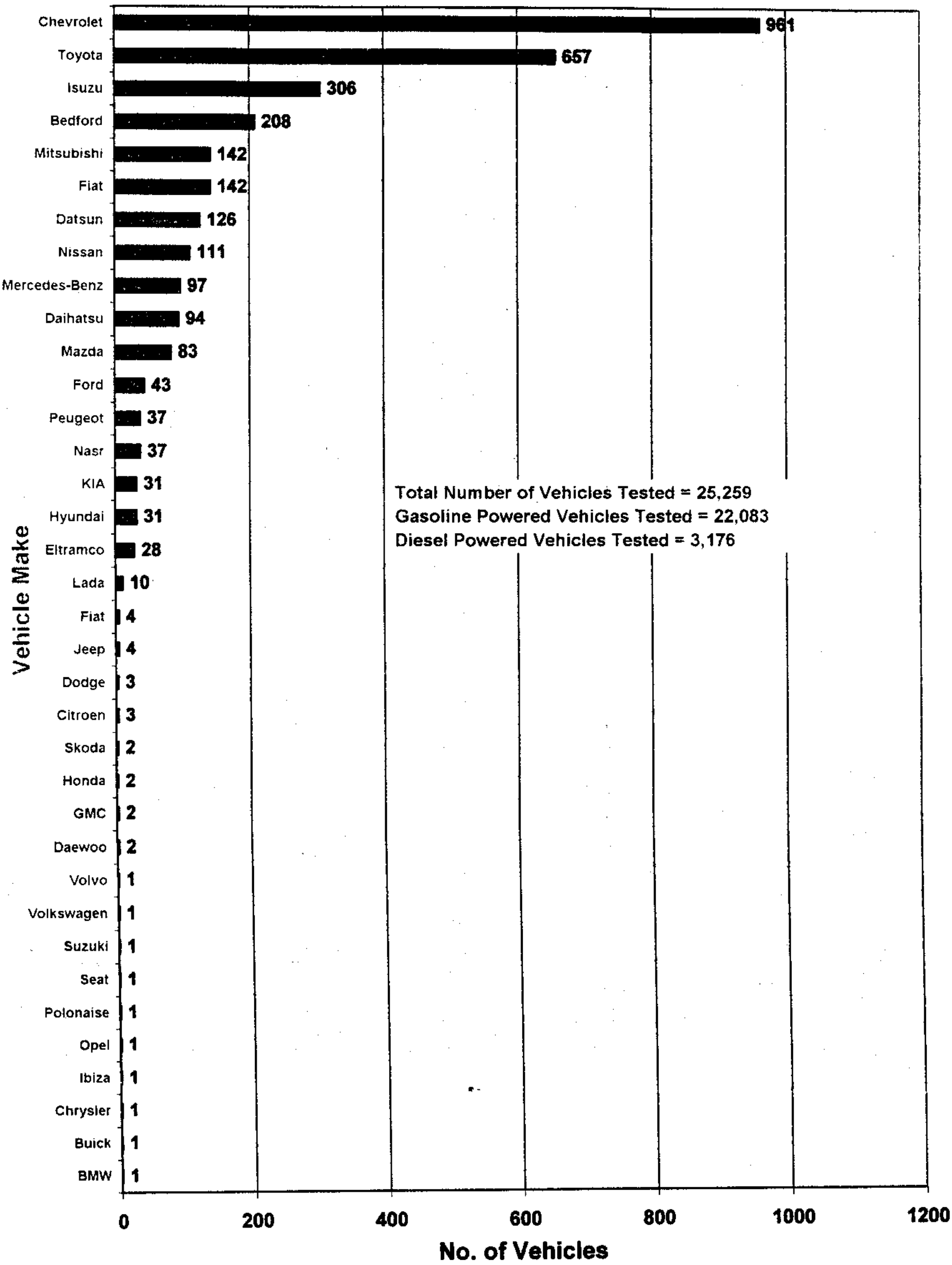
Total Vehicles Tested = 22, 083

Table 3.5

Gasoline Powered Vehicle Makes

No.	Make	No. Tested	% of Total	Cumulative%
1	Fiat	4214	19.1%	19.08%
2	Peugeot	3230	14.6%	33.71%
3	Nasr	3014	13.6%	47.36%
4	Lada	1091	4.9%	52.30%
5	Suzuki	1045	4.7%	57.03%
6	Toyota	1001	4.5%	61.56%
7	Mercedes-Benz	953	4.3%	65.88%
8	Hyundai	867	3.9%	69.80%
9	Datsun	643	2.9%	72.72%
10	Mazda	575	2.6%	75.32%
11	Mitsubishi	546	2.5%	77.79%
12	Renault	438	2.0%	79.78%
13	Zastava	418	1.9%	81.67%
14	Opel	395	1.8%	83.46%
15	Jeep	370	1.7%	85.13%
16	Volkswagen	332	1.5%	86.64%
17	Daewoo	316	1.4%	88.07%
18	Seat	305	1.4%	89.45%
19	Polonaise	286	1.3%	90.74%
20	Chevrolet	224	1.0%	91.76%
21	Pony	186	0.8%	92.60%
22	BMW	171	0.8%	93.37%
23	Honda	171	0.8%	94.15%
24	Citroen	153	0.7%	94.84%
25	Nissan	151	0.7%	95.53%
26	Volvo	133	0.6%	96.13%
27	Daihatsu	128	0.6%	96.71%
28	Ford	123	0.6%	97.26%
29	KIA	107	0.5%	97.75%
30	Skoda	88	0.4%	98.15%
31	Buick	74	0.3%	98.48%
32	Dodge	60	0.3%	98.75%
33	Isuzu	56	0.3%	99.01%
34	Bedford	36	0.2%	99.17%
35	Dacia	34	0.2%	99.33%
36	Niva	27	0.1%	99.45%
37	Audi	22	0.1%	99.55%
38	Chrysler	18	0.1%	99.63%
39	Lancia	14	0.1%	99.69%
40	Subaru	14	0.1%	99.76%
41	Alfa Romeo	7	0.0%	99.79%
42	Cadillac	7	0.0%	99.82%
43	Eltramco	7	0.0%	99.85%
44	Samsung	7	0.0%	99.88%
45	Jaguar	6	0.0%	99.91%
46	Ibiza	5	0.0%	99.93%
47	Land Rover	5	0.0%	99.95%
48	Aleco	2	0.0%	99.96%
49	Vitara	2	0.0%	99.97%
50	Console	1	0.0%	99.98%
51	Copel	1	0.0%	99.98%
52	GMC	1	0.0%	99.99%
53	Talbot	1	0.0%	99.99%
54	Tavria	1	0.0%	100.00%
55	Tawnas	1	0.0%	100.00%

Figure 3.4
Diesel Powered Vehicles Tested by Make



Total Vehicles Tested = 3,176

Table 3.6
Diesel Powered Vehicle Makes

No.	Make	No. Tested	% of Total	Cumulative %
1	Chevrolet	961	30.3%	30.26%
2	Toyota	657	20.7%	50.94%
3	Isuzu	306	9.6%	60.58%
4	Bedford	208	6.5%	67.13%
5	Fiat	142	4.5%	71.60%
6	Mitsubishi	142	4.5%	76.07%
7	Datsun	126	4.0%	80.04%
8	Nissan	111	3.5%	83.53%
9	Mercedes-Benz	97	3.1%	86.59%
10	Daihatsu	94	3.0%	89.55%
11	Mazda	83	2.6%	92.16%
12	Ford	43	1.4%	93.51%
13	Nasr	37	1.2%	94.68%
14	Peugeot	37	1.2%	95.84%
15	Hyundai	31	1.0%	96.82%
16	KIA	31	1.0%	97.80%
17	Eltramco	28	0.9%	98.68%
18	Lada	10	0.3%	98.99%
19	Jeep	4	0.1%	99.12%
20	Fiat	4	0.1%	99.24%
21	Citroen	3	0.1%	99.34%
22	Dodge	3	0.1%	99.43%
23	Daewoo	2	0.1%	99.50%
24	GMC	2	0.1%	99.56%
25	Honda	2	0.1%	99.62%
26	Skoda	2	0.1%	99.69%
27	BMW	1	0.0%	99.72%
28	Buick	1	0.0%	99.75%
29	Chrysler	1	0.0%	99.78%
30	Ibiza	1	0.0%	99.81%
31	Opel	1	0.0%	99.84%
32	Polonaise	1	0.0%	99.87%
33	Seat	1	0.0%	99.91%
34	Suzuki	1	0.0%	99.94%
35	Volkswagen	1	0.0%	99.97%
36	Volvo	1	0.0%	100.00%

SECTION 4
EMISSIONS TEST RESULTS

The following discussion presents an analysis of the results of the emissions testing effort from February through October 1999. The analysis is divided into three subsections to address key information from the ORT effort: 1) the level of emissions from the vehicle population; 2) the rate of compliance with the Executive Regulations of law No. 4; and 3) the magnitude of non-compliance. This final analysis provides valuable information to assess the challenges faced in bringing the fleet into compliance with existing regulations or for planning for changes to these regulations.

4.1 Rate of Compliance

Article 37 of Executive Decree No. 338, year 1995, of Law 4 specifies carbon monoxide (CO) and hydrocarbon (HC) limits for gasoline vehicles and opacity limits for diesel vehicles. Limits for each pollutant are different for model years pre-1995 and 1995 and later. These limits are given in Table 4.1.

4.1.1 Gasoline Vehicles

Results for the gasoline vehicle population are presented in Table 4.2. Overall failure rates for the program are between 31% and 39%, depending on the age of the vehicle. This result represents a relatively high failure rate in relation to targets typically set for vehicle testing and tune-up programs. It will be important to validate and consider these rates in starting model VET center operations and in the final design of the VET program for Greater Cairo. There is no clear pattern in the pre-and post-1995 populations in terms of pass/fail rates for the individual pollutants.

Table 4.3 shows the compliance rates for both gasoline and diesel vehicles by model year. For gasoline vehicles, compliance rate varies widely over the model years tested. The only clear trend is that in later years (about 1991 to 1999), the CO compliance rate is very high, generally exceeding 80% and rising to 99% in 1999. For HC, there is a relatively smooth increase in compliance rates starting from about model year 1971 (70%) and rising to model year 1999 (98%).

Table 4.4 shows the compliance rates for both gasoline and diesel vehicles by vehicle type. Passenger vehicles and taxis, the two largest categories of gasoline-powered vehicle types, show high levels of compliance for CO (92% and 84%, respectively), but much lower levels of compliance for HC (68% and 85%, respectively).

4.1.2 Diesel Vehicles

Compliance with the diesel standard is very high and shows no significant variation between the two age classes of vehicles, even considering that the two classes have different emissions limits (Tables 4.3 and 4.5). It is suspected that this high compliance rate may be partly attributable to the more difficult test procedure (acceleration/deceleration) and refining of the test methodology may be needed before drawing further conclusions on the basis of the results gathered. Specifically, standard test procedures (SAE-J1667) require snap acceleration up to the maximum engine speed, three times in a row. To achieve this condition the ORT inspectors would need to operate the vehicle instead of the motorist. This condition is not allowed by the current regulations governing on road inspection of vehicles.

4.2 Level of Emissions

4.2.1 Gasoline-Powered Vehicles

Several graphical plots were generated to present the distribution of emissions values from the gasoline vehicles tested. The hydrocarbon emissions data displayed in Figures 4.1 and 4.2 show that there are significant reductions in levels emitted by newer vehicles. The average HC concentrations for vehicle models 1995 and newer are approximately half of those in the older vehicle class. This result leads to a higher compliance rate for newer vehicles even though the limit is reduced from 1,000 PPM to 900 PPM. Hydrocarbon data from both vehicle age classes are highly skewed, with the median emissions value substantially below the mean level.

The carbon monoxide emissions data displayed in Figures 4.3 and 4.4 also demonstrate significant reductions in moving from the pre-1995 to the 1995 and later vehicle classes. Nearly half of the older vehicles have CO emissions at or above the limit of 4.5% set for the newer vehicles. The data are relatively normally distributed around this level. Data for the newer vehicles are skewed, with a higher percentage showing low emissions; slightly more than 10 percent of the older vehicles show CO levels less than 1%, whereas 30% of the newer vehicles have emissions in this range.

As shown in Section 3, taxis and passenger vehicles dominate gasoline-powered vehicles. Figure 4.5 is a composite plot displaying the rates of failure and compliance for these two vehicle types for all vehicle years. Passenger vehicles have a slightly higher rate of compliance than taxis (65.1% vs 60.7%).

4.3 Discussion of Compliance and Standards

A set of graphs was plotted to examine the relationship among the level of compliance, the size of the vehicle population emitting pollutants, and the magnitude of the emissions. Figures 4.9 and 4.10 pertain to HC emissions, and Figures 4.11 and 4.12 pertain to CO emissions, both from gasoline-powered vehicles. Figures 4.13 and 4.14 pertain to opacity measurements (smoke emissions) from diesel-powered vehicles.

The Figures were drawn by plotting the cumulative frequency distribution of vehicles emitting a particular pollutant (HC, CO, or opacity) and by plotting the cumulative frequency of the actual emissions. The cumulative frequency values, given in percent, of vehicles emitting a pollutant also represent the distribution of the vehicle population. For example, looking at HC emissions for model years before 1995 (Figure 4.9), 80% of the vehicles emitted HC at a level of about 1,200-PPM. However, the graph can also be read as 20% of the vehicles were responsible for emitting high levels of HC (greater than 1,200).

In the same way, looking at the corresponding level of emissions, 20% (80% on the cumulative distribution scale) of the vehicles emitted about 50% of the pollution (the worst 50% values of HC). 30% of the vehicles (70% on the cumulative distribution scale) emitted about 65% of the pollution (the worst 65% of values of HC, corresponding to a reading of 35% on the cumulative distribution scale).

The following discussion uses this method of comparing the distribution of vehicles versus the level of emissions.

4.3.1 Hydrocarbon Emissions In Gasoline-Powered Vehicles Before 1995

Figure 4.9 is a summary of the cumulative frequency distribution of hydrocarbon emissions by number of vehicles and the cumulative frequency of hydrocarbon emissions for gasoline-powered vehicles before 1995. Ten percent of the vehicles tested produced about 33 % of the hydrocarbon emissions, and twenty percent of the vehicles tested produced about 50% of the hydrocarbon emissions. At the HC limit in Law 4 of 1,000 PPM, about 25% of the vehicles produced about 56% of the HC emissions. Therefore, if the HC limit were enforced by emissions testing and met by tuning up the current vehicle population, 56% of the HC pollution from this group of vehicles would be eliminated.

4.3.2 Hydrocarbon Emissions in Gasoline-Powered Vehicles 1995 and after

Figure 4.10 is the same plot for vehicle model years 1995 and after. Ten percent of the vehicles tested produced about 35% of the HC emissions, and twenty percent of the vehicles tested produced about 53% of the HC emissions. At the HC limit in Law 4 of 900 PPM, about seven percent of the vehicles produced about 30% of the HC emissions. Therefore, if the HC limit were enforced by emissions testing and met by tuning up the current vehicle population, 30% of the HC pollution from this group of vehicles would be eliminated.

4.3.3 Carbon Monoxide Emissions in Gasoline-Powered Vehicles Before 1995

Figure 4.11 is a summary of the cumulative frequency distribution of carbon monoxide (CO) emissions by number of vehicles and the cumulative frequency of CO emissions for gasoline-powered vehicles before 1995. Ten percent of the vehicles tested produced about 20% of the CO emissions, and twenty percent of the vehicles tested produced about 38% of the CO emissions. At the CO limit in Law 4 of 7%, about 25% of the vehicles produced about 45% of the CO emissions. Therefore, if the CO limit were enforced by emissions testing and met by tuning up the current vehicle population, 45% of the CO pollution from this group of vehicles would be eliminated.

4.3.4 Carbon Monoxide Emissions in Gasoline-Powered Vehicles 1995 and after

Figure 4.12 is the same plot for vehicle model years 1995 and after. Ten percent of the vehicles tested produced about 28 % of the CO emissions, and twenty percent of the vehicles tested produced about 49% of the CO emissions. At the CO limit in Law 4 of 4.5%, about 32% of the vehicles produced about 69% of the CO emissions. Therefore, if the CO limit were enforced by emissions testing and met by tuning up the current vehicle population, 69% of the CO pollution from this group of vehicles would be eliminated.

Figure 4.1

Pre-1995 Gasoline Powered Vehicle Models HC Data

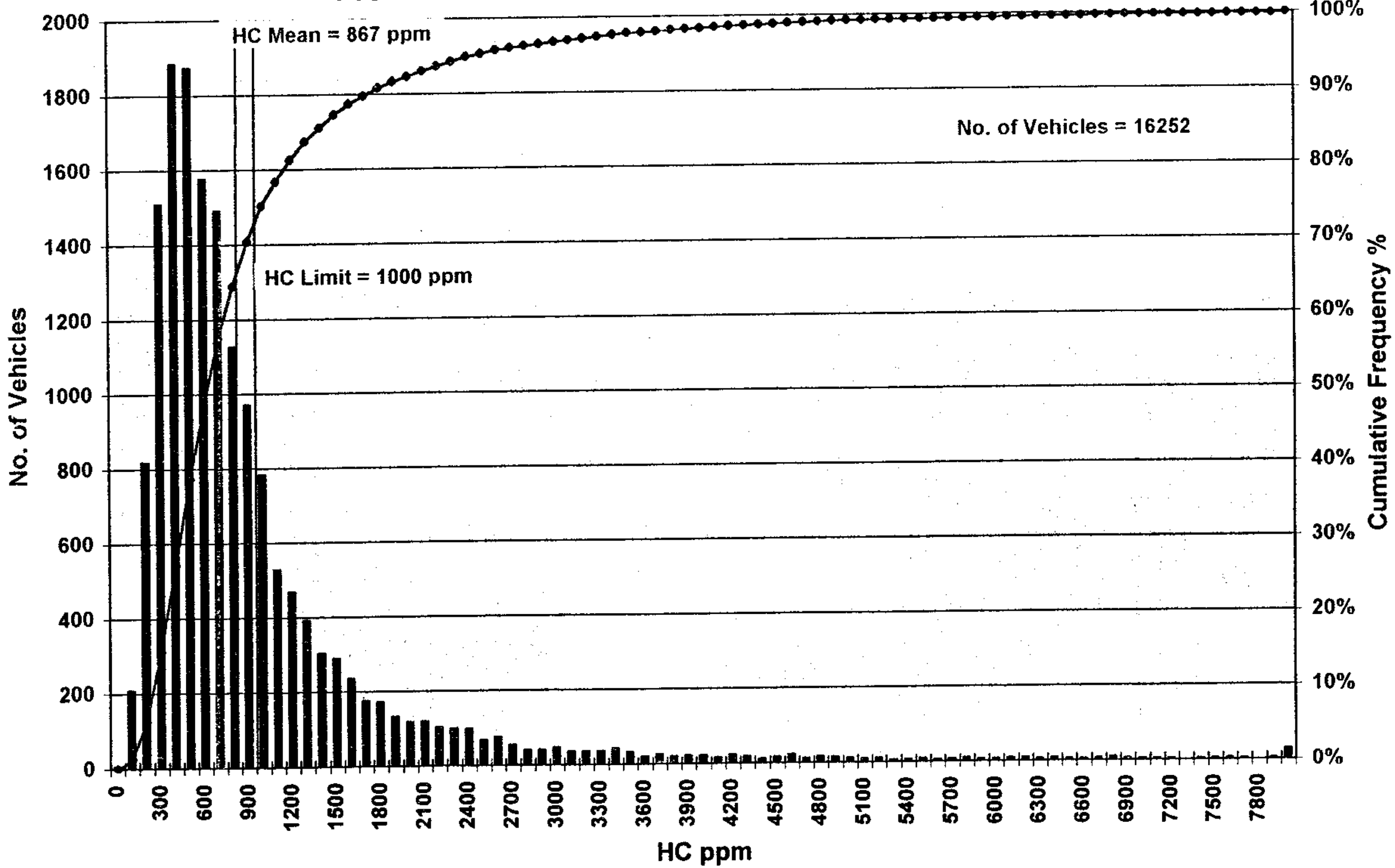


Figure 4.2

1995 and After Gasoline Powered Vehicle Models HC Data

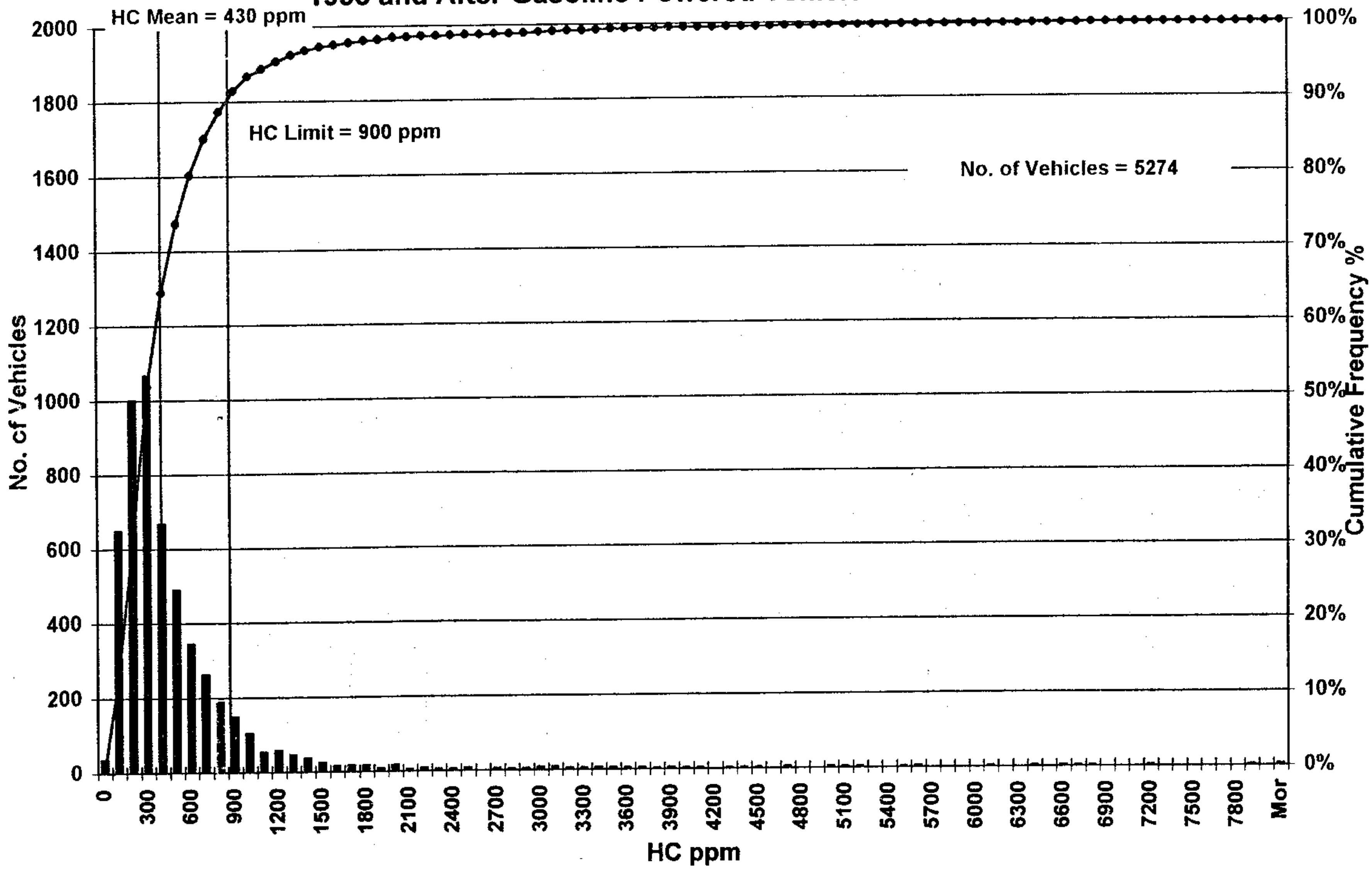


Table 4.1. Compliance Limits in Law 4

	Pre-1995	1995 and later
Gasoline		
HC (ppm)	1,000	900
CO (%)	7	4.5
Diesel		
Opacity (%)	65	50

Table 4.2. Compliance Rates for Gasoline Vehicles.

	Pre-1995 (5,291 vehicles)			1995 and after (16,399 vehicles)		
Outcome	HC	CO	Overall*	HC	CO	Overall*
Pass	75%	75%	61%	91%	71%	69%
Fail	25%	25%	39%	9%	29%	31%

Table 4.3
Vehicles Compliance Rates by Model Year

Gasoline Vehicles			Diesel Vehicles	
Year	*CO Compliance %*	*HC Compliance %*	*Year*	*Compliance %*
1954	0%	0%	1959	100%
1956	25%	33%	1961	100%
1957	95%	100%	1962	100%
1958	65%	71%	1963	100%
1959	32%	45%	1964	89%
1960	67%	67%	1965	100%
1961	89%	75%	1966	100%
1962	23%	62%	1967	100%
1963	65%	35%	1968	100%
1964	65%	62%	1970	100%
1965	39%	45%	1971	100%
1966	64%	50%	1972	100%
1967	71%	69%	1973	100%
1968	74%	71%	1974	100%
1969	59%	51%	1975	100%
1970	69%	59%	1976	90%
1971	73%	70%	1977	91%
1972	87%	65%	1978	100%
1973	86%	74%	1979	94%
1974	45%	68%	1980	99%
1975	36%	71%	1981	94%
1976	39%	70%	1982	97%
1977	72%	75%	1983	98%
1978	75%	75%	1984	98%
1979	43%	76%	1985	100%
1980	48%	72%	1986	97%
1981	81%	75%	1987	100%
1982	52%	75%	1988	98%
1983	61%	73%	1989	98%
1984	79%	74%	1990	100%
1985	83%	76%	1991	100%
1986	74%	81%	1992	100%
1987	92%	74%	1993	100%
1988	53%	78%	1994	99%
1989	59%	81%	1995	97%
1990	77%	80%	1996	100%
1991	86%	79%	1997	98%
1992	92%	83%	1998	99%
1993	94%	91%	1999	92%
1994	82%	88%		
1995	86%	85%		
1996	89%	88%		
1997	96%	92%		
1998	96%	92%		
1999	99%	98%		

Table 4.4.
Vehicle Types Compliance Rates

Types	Compliance Rates		
	CO Compliance %	HC Compliance %	Opacity Compliance %
Passenger	92%	68%	98%
Taxi	84%	85%	99%
Truck	47%	75%	96%
Bus/Van	58%	67%	100%

Table 4.5. Compliance Rates for Diesel Vehicle Opacity Measurements.

Outcome	Pre-1995 (1,894 vehicles)	1995 and after (1,136 vehicles)
Pass	98%	99%
Fail	2%	1%

Figure 4.3
Pre 1995 Gasoline Powered Vehicle Models CO Data

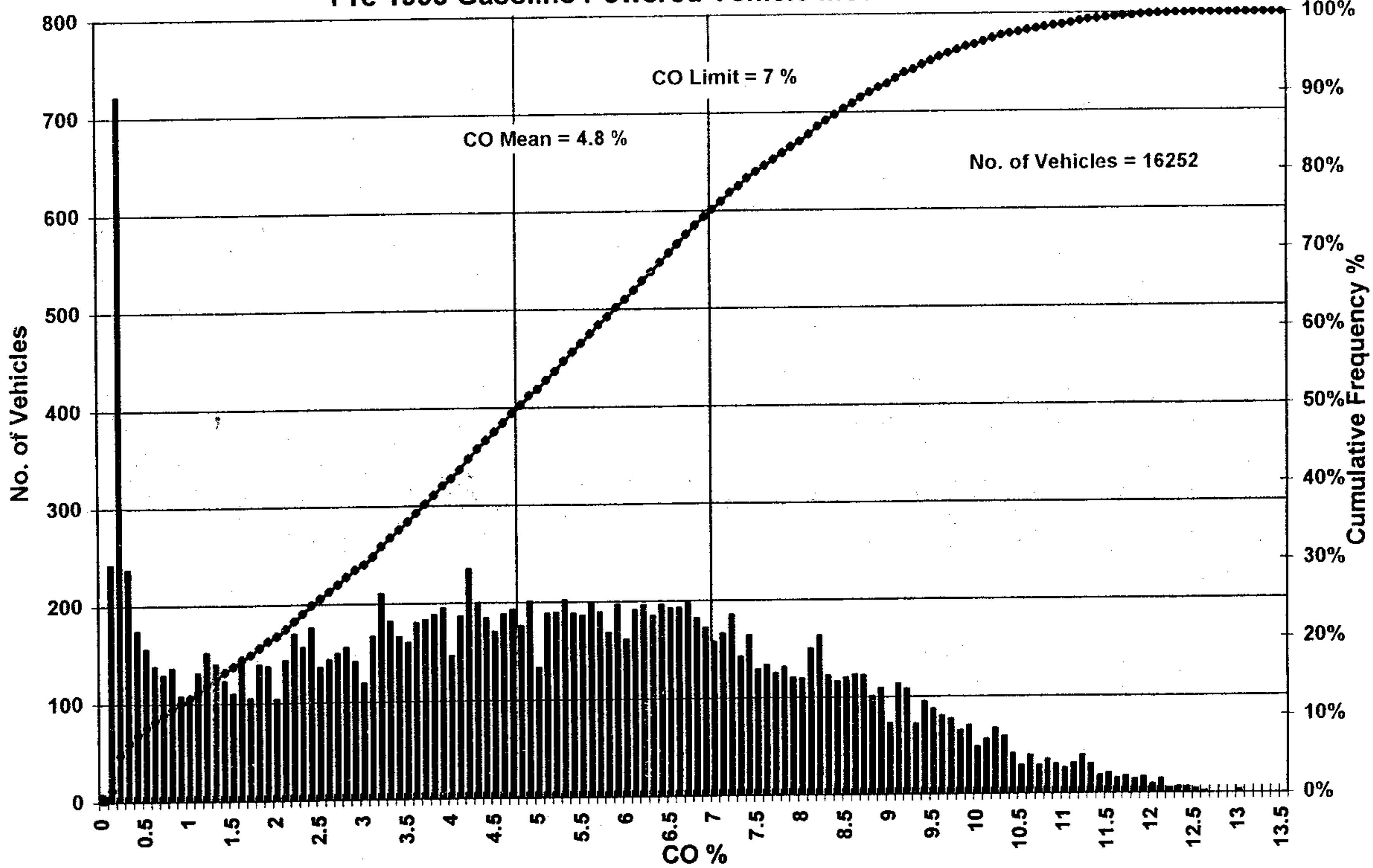


Figure 4.4
1995 and After Gaoline Powered Vehicle Models CO Data

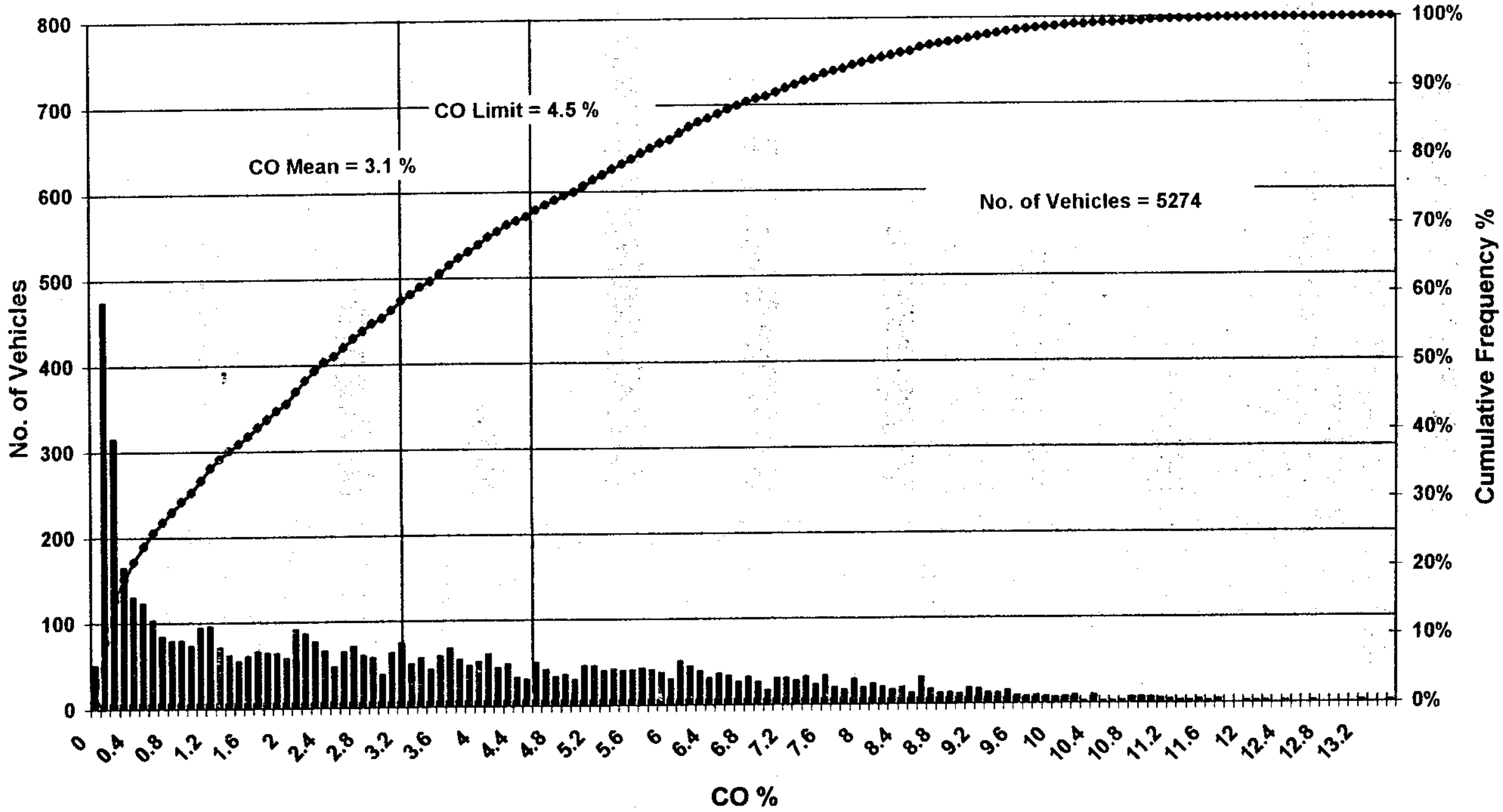


Figure 4.5
Dominant Gasoline Powered Vehicle Types Compliance Rates

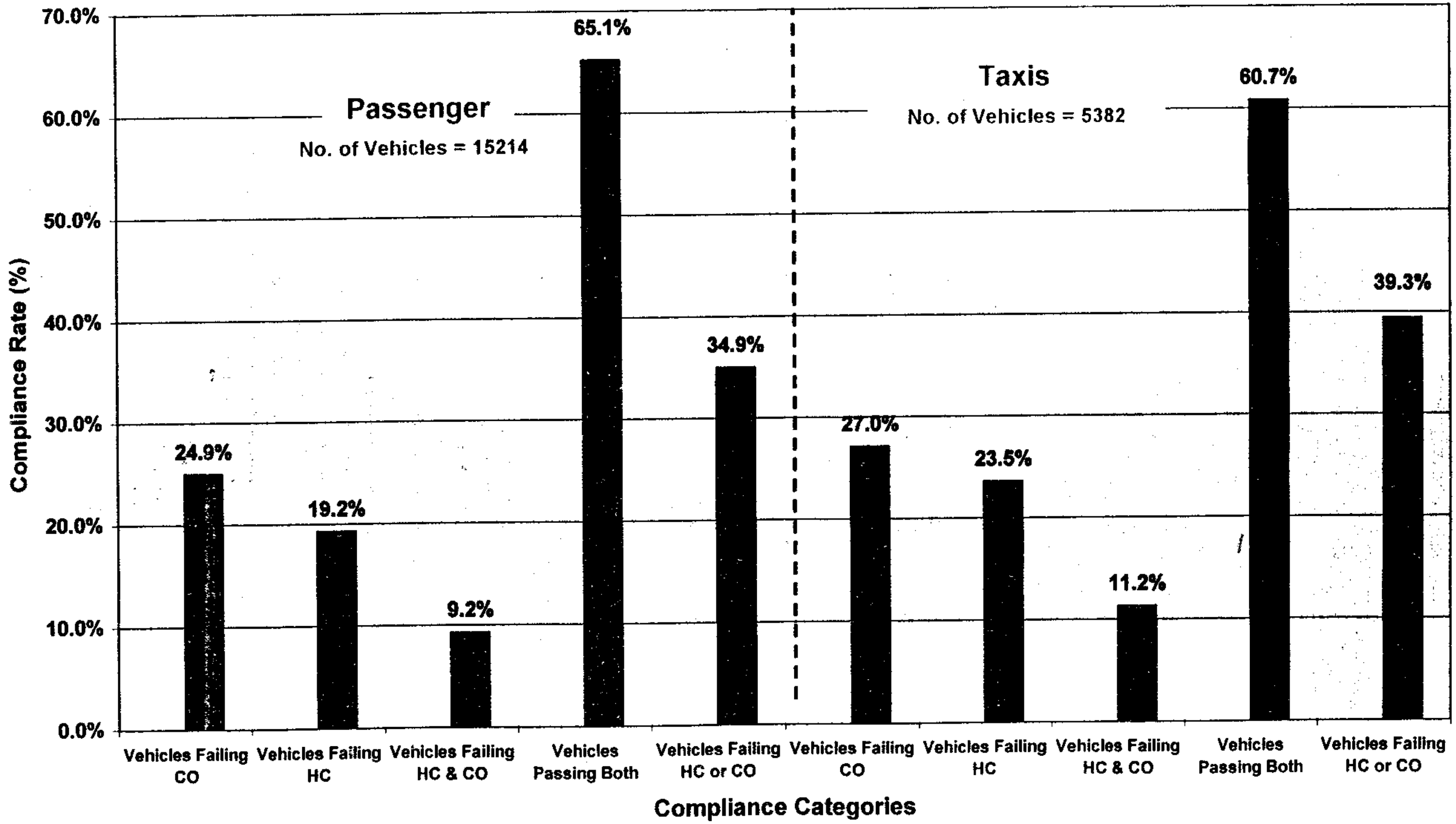


Figure 4.6

Pre 1995 Diesel Powered Vehicles Opacity Data

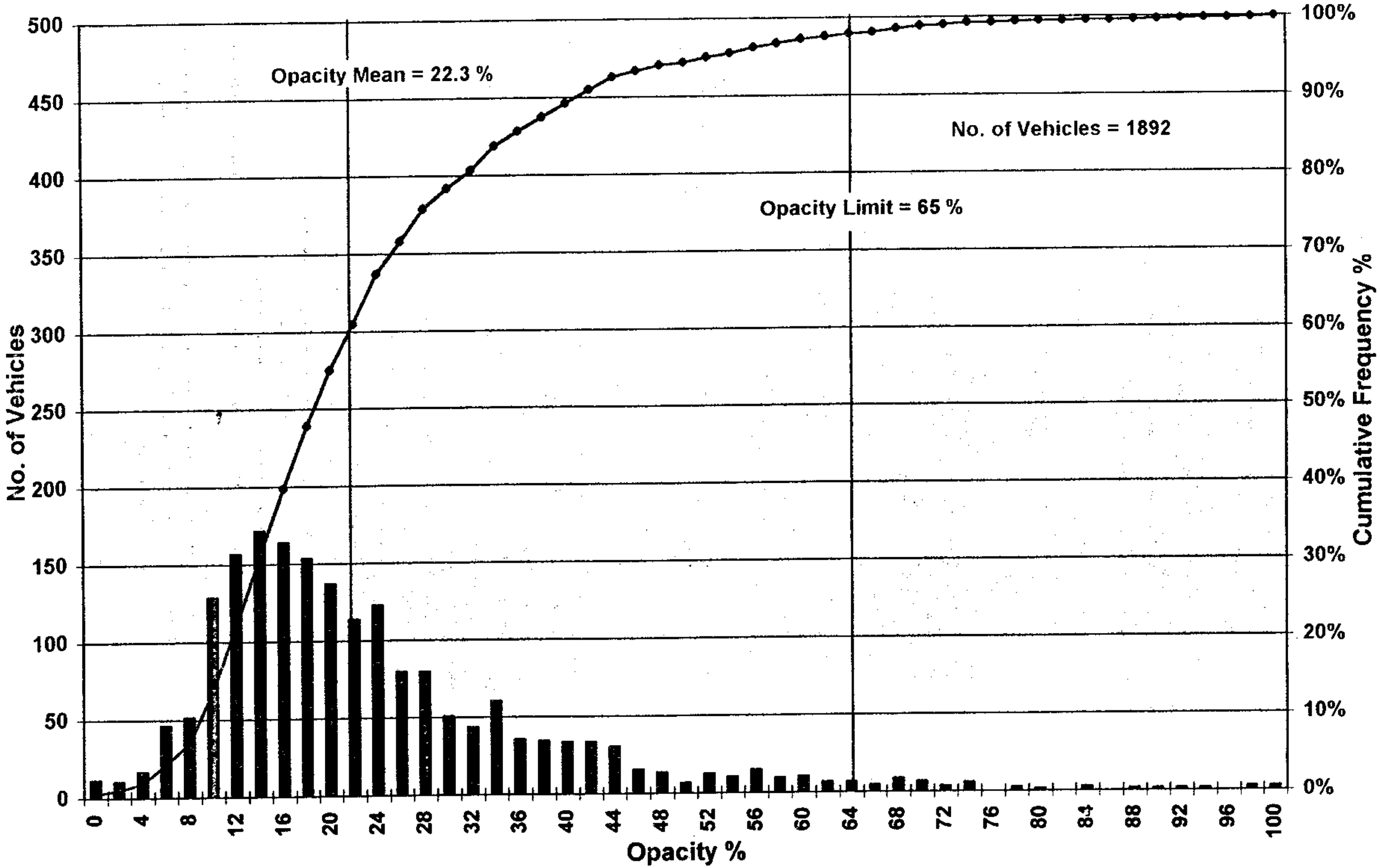


Figure 4.7
1995 and After Diesel Powered Vehicle Models Opacity Data

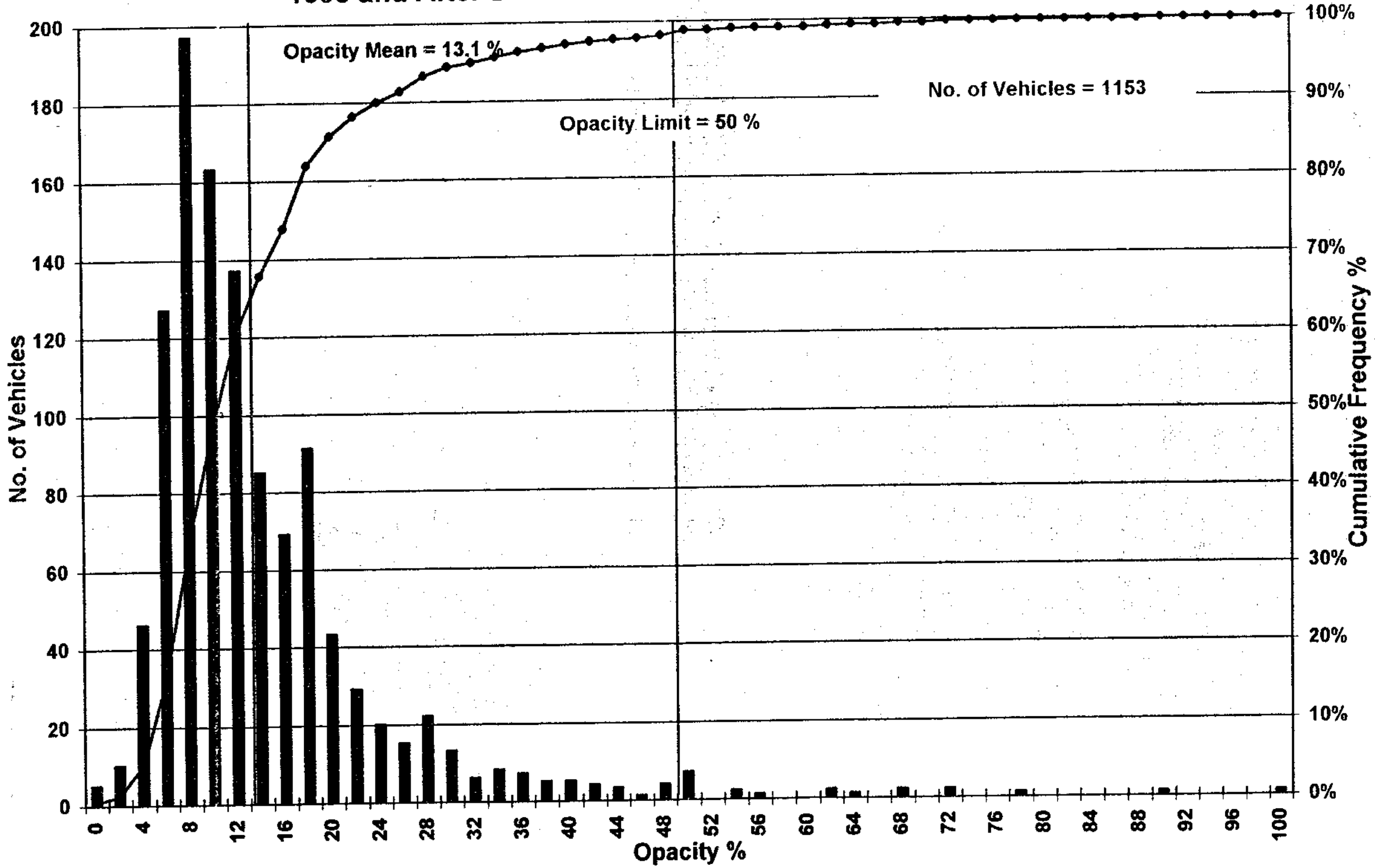


Figure 4.8
Dominant Diesel Powered Vehicle Types Compliance Rates

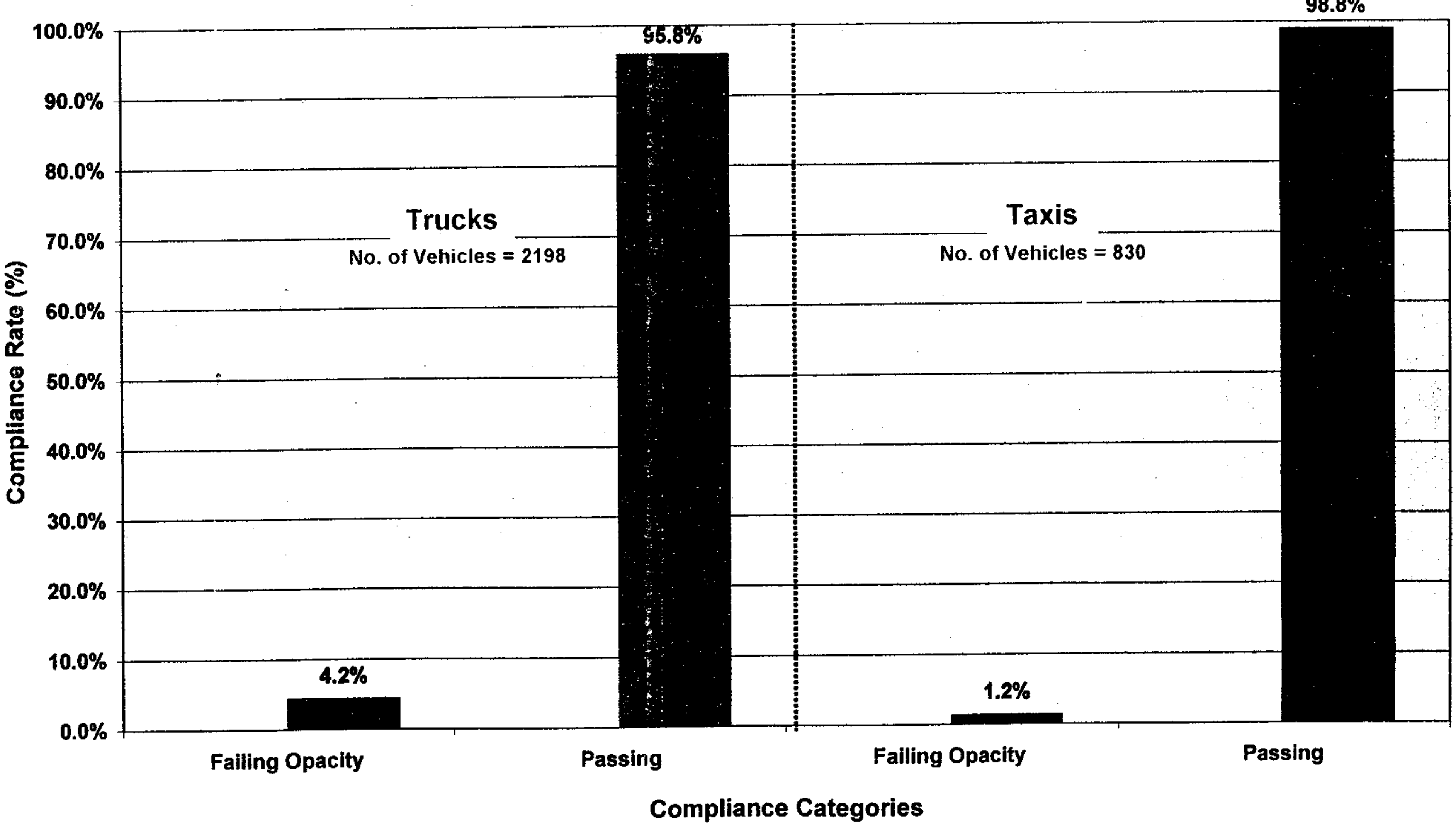


Figure 4.9
Cumulative Distribution of HC Emissions
Gasoline Powered Vehicle Model Years Pre 1995

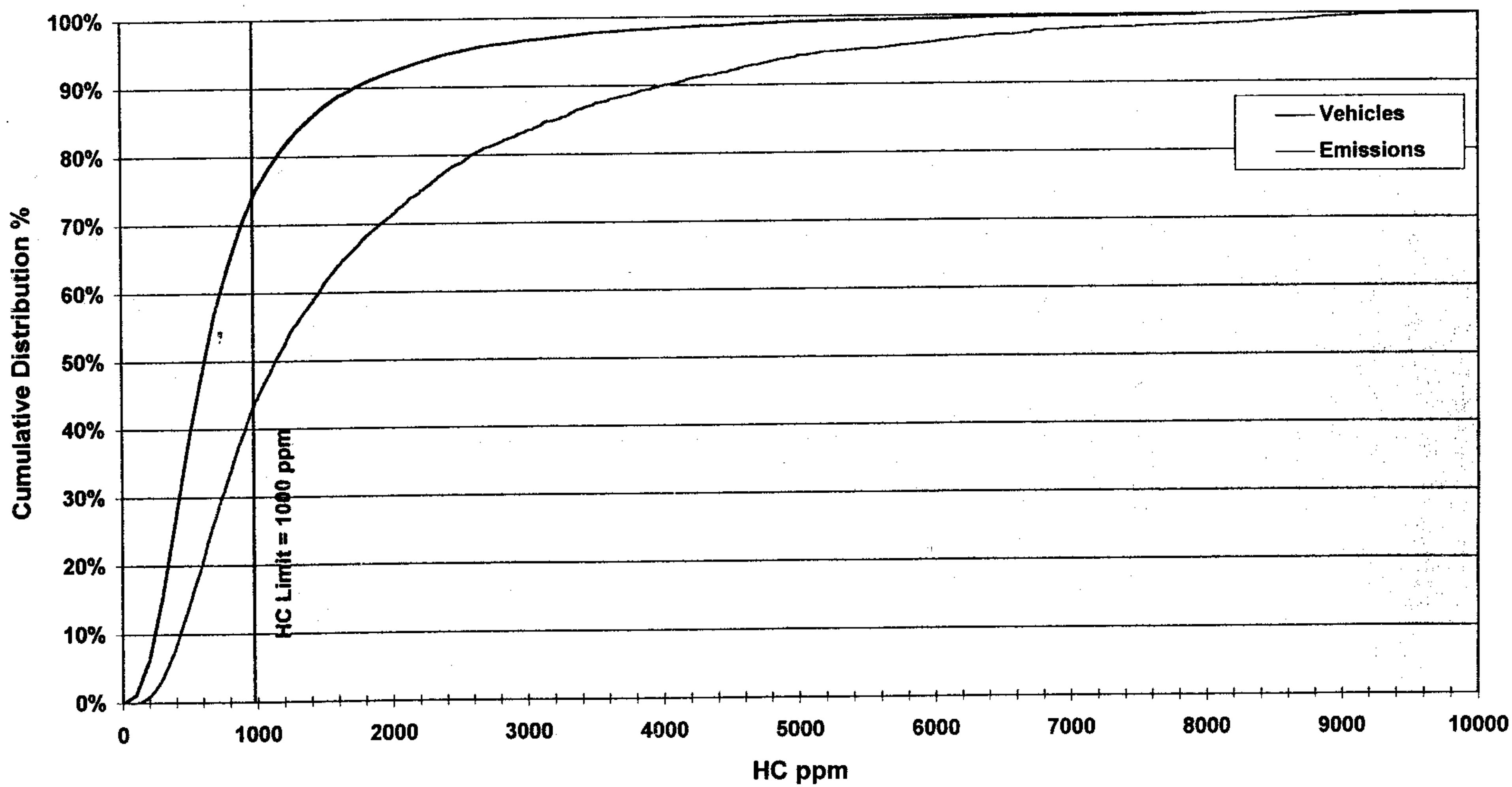


Figure 4.10
Cumulative Distribution of HC Emissions
Gasoline Powered Vehicle Model Years 1995 and After

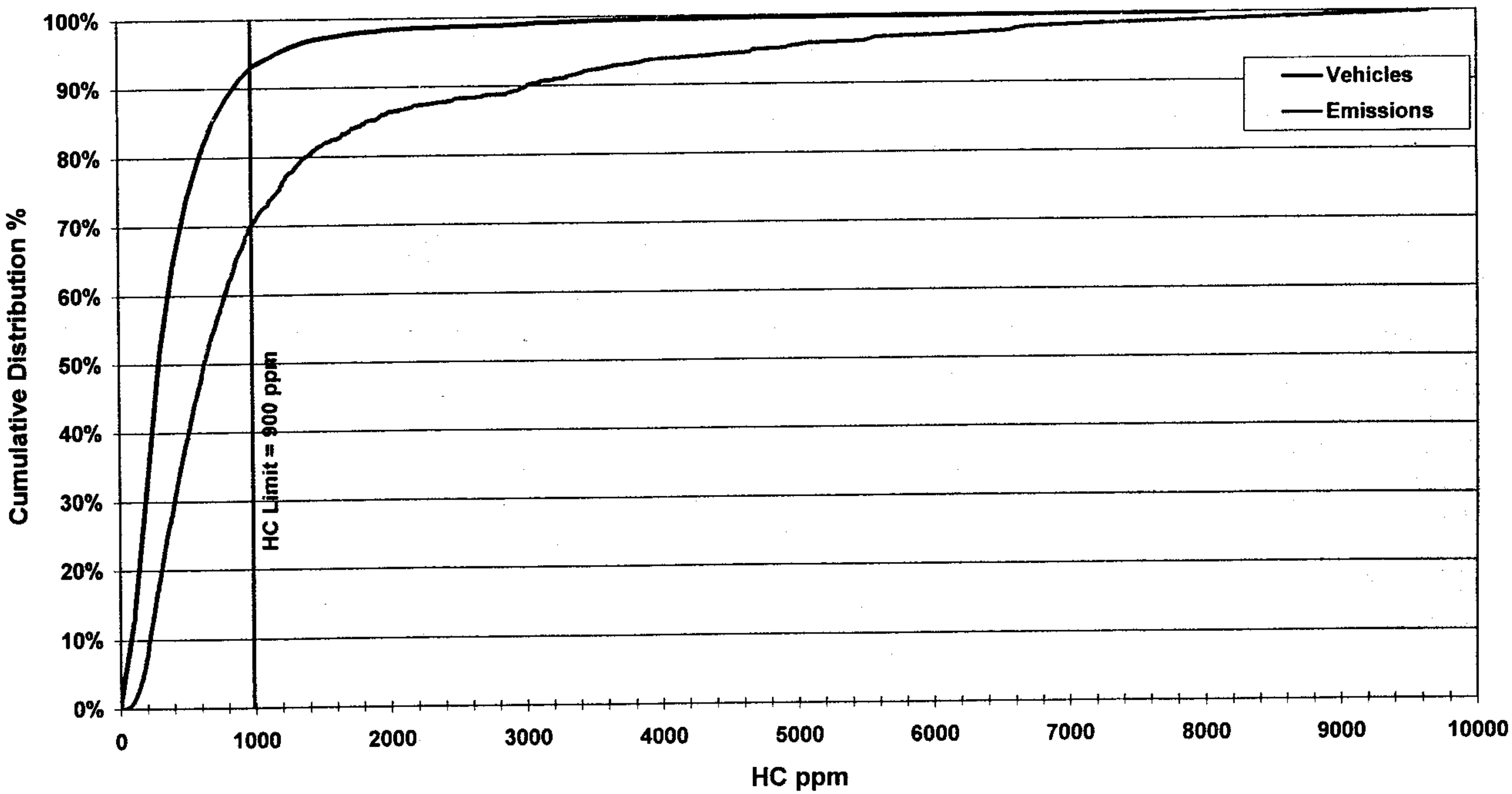


Figure 4.11
Cumulative Distribution of CO Emissions
Gasoline Powered Vehicle Model Years Pre 1995

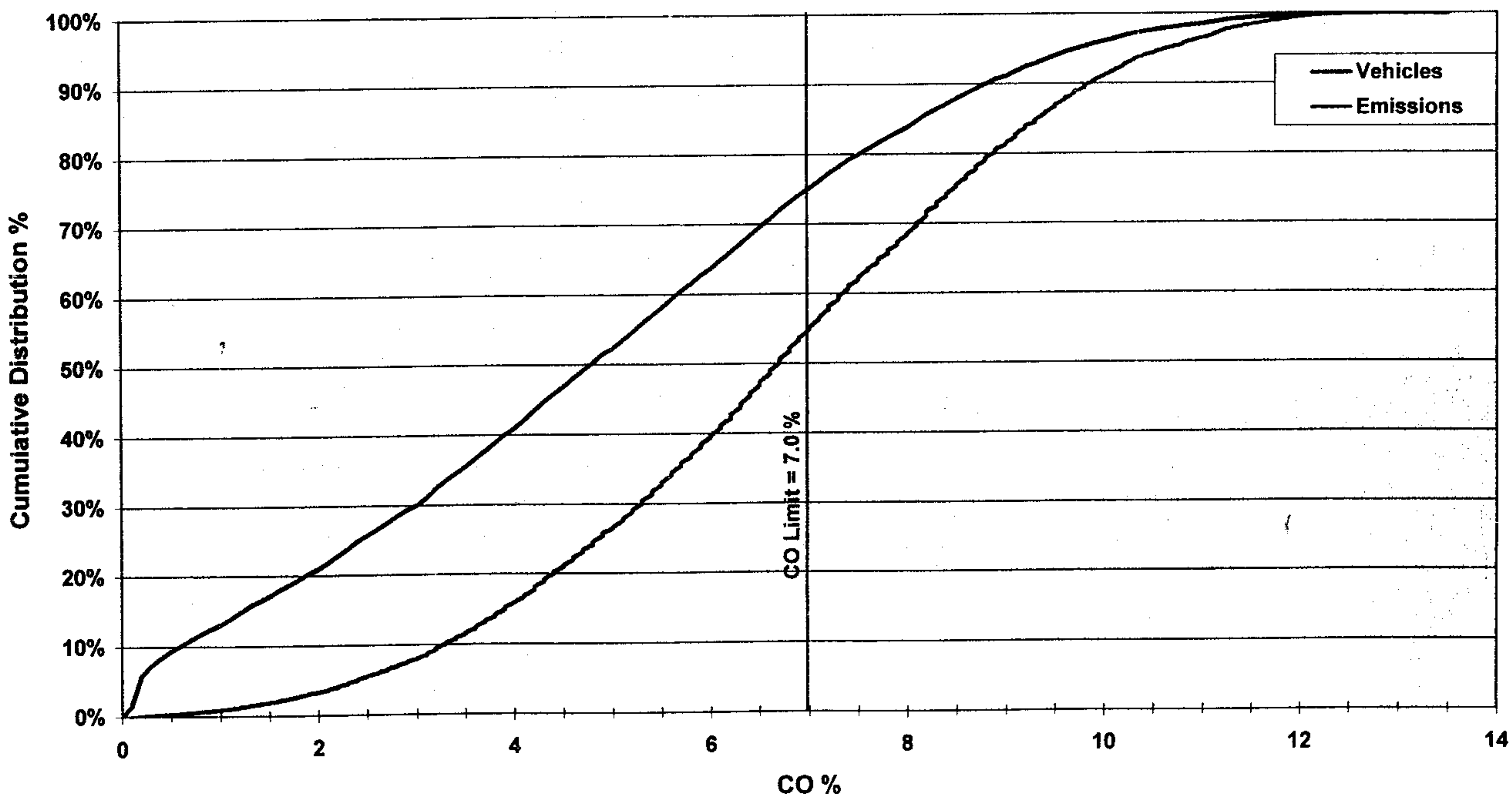


Figure 4.12
Cumulative Distribution of CO Emissions
Gasoline Powered Vehicle Model Years 1995 and After

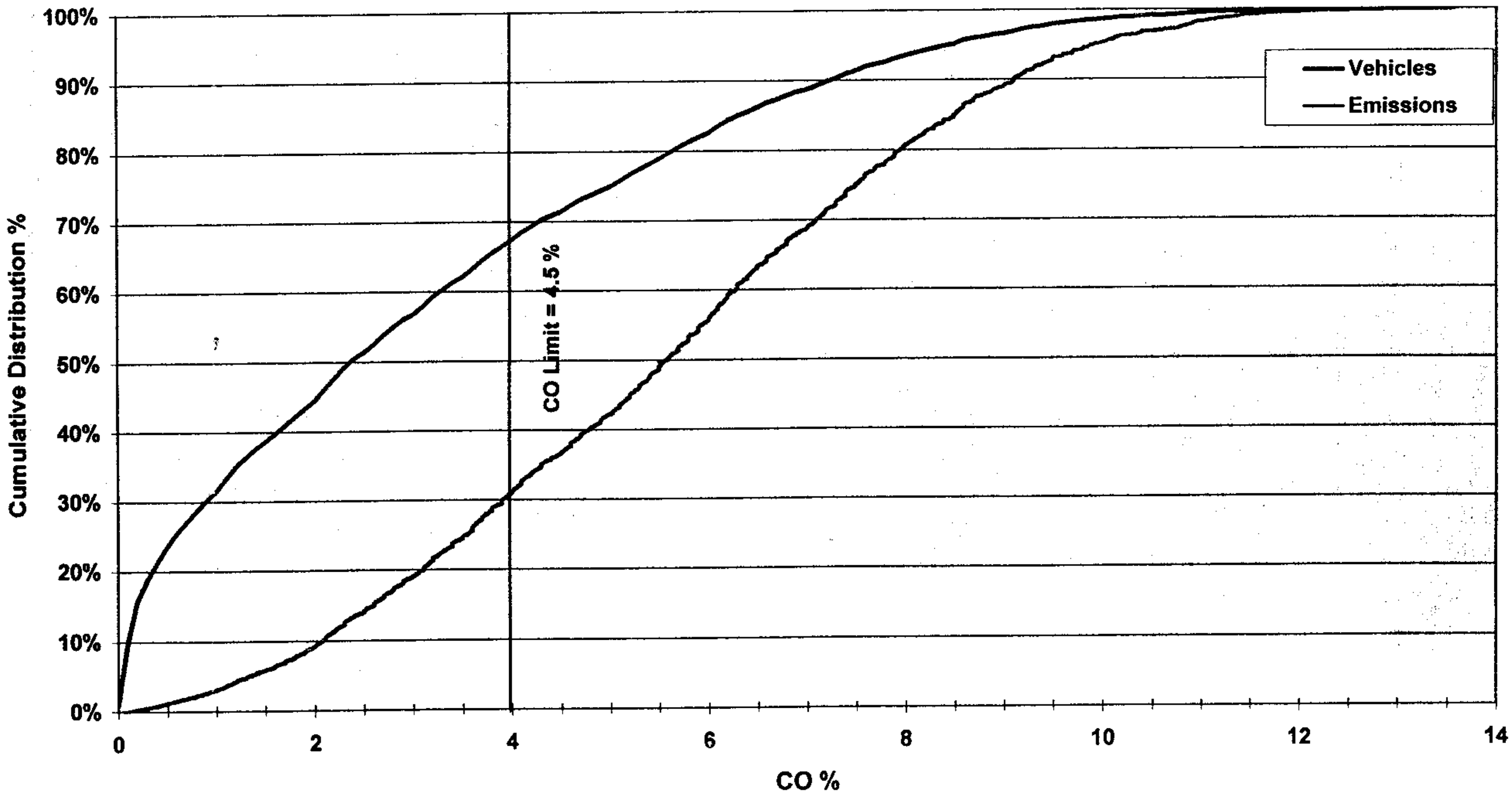


Figure 4.13
Cumulative Distribution of Opacity Readings
Diesel Powered Vehicle Model Years Pre 1995

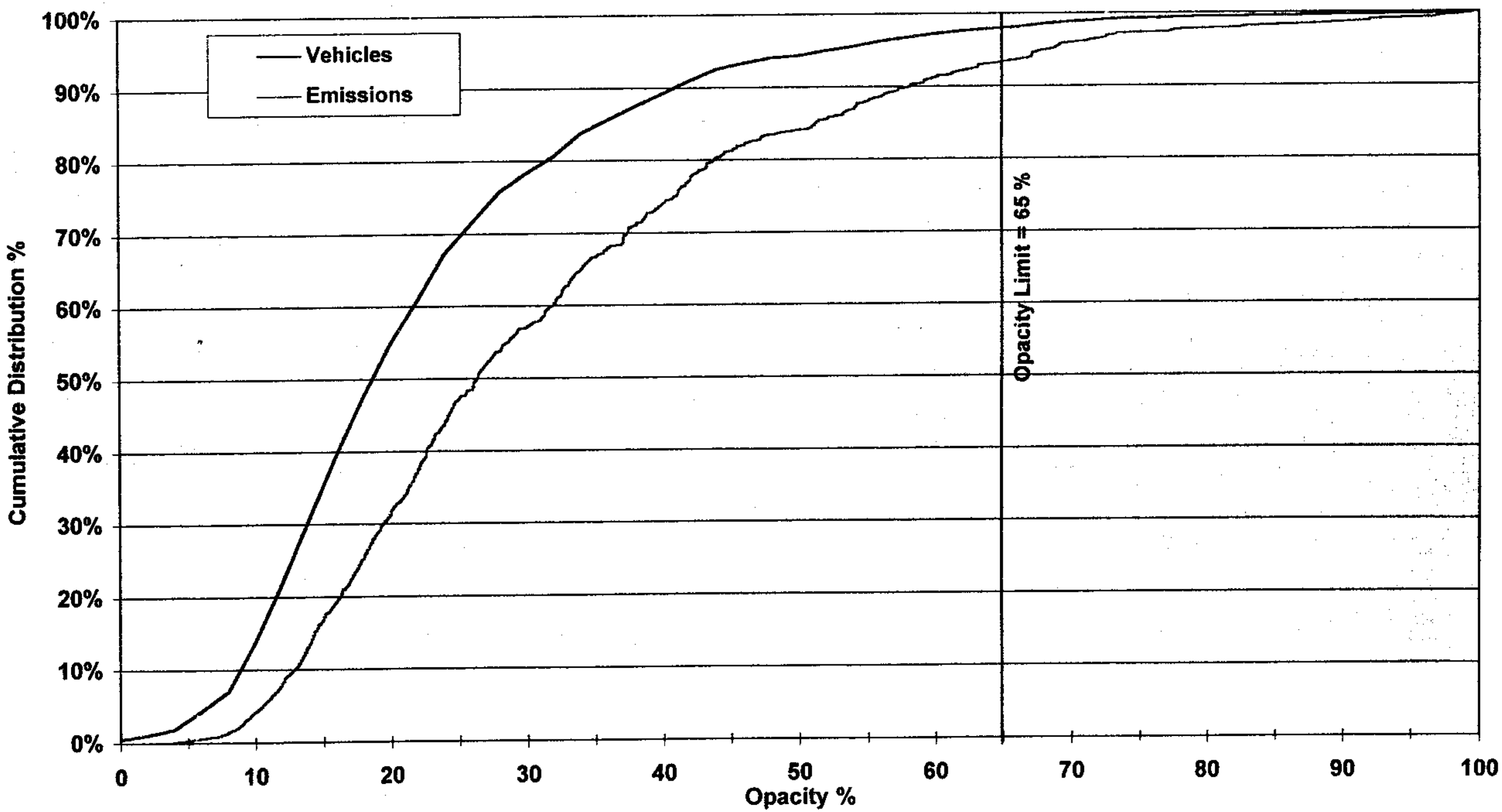
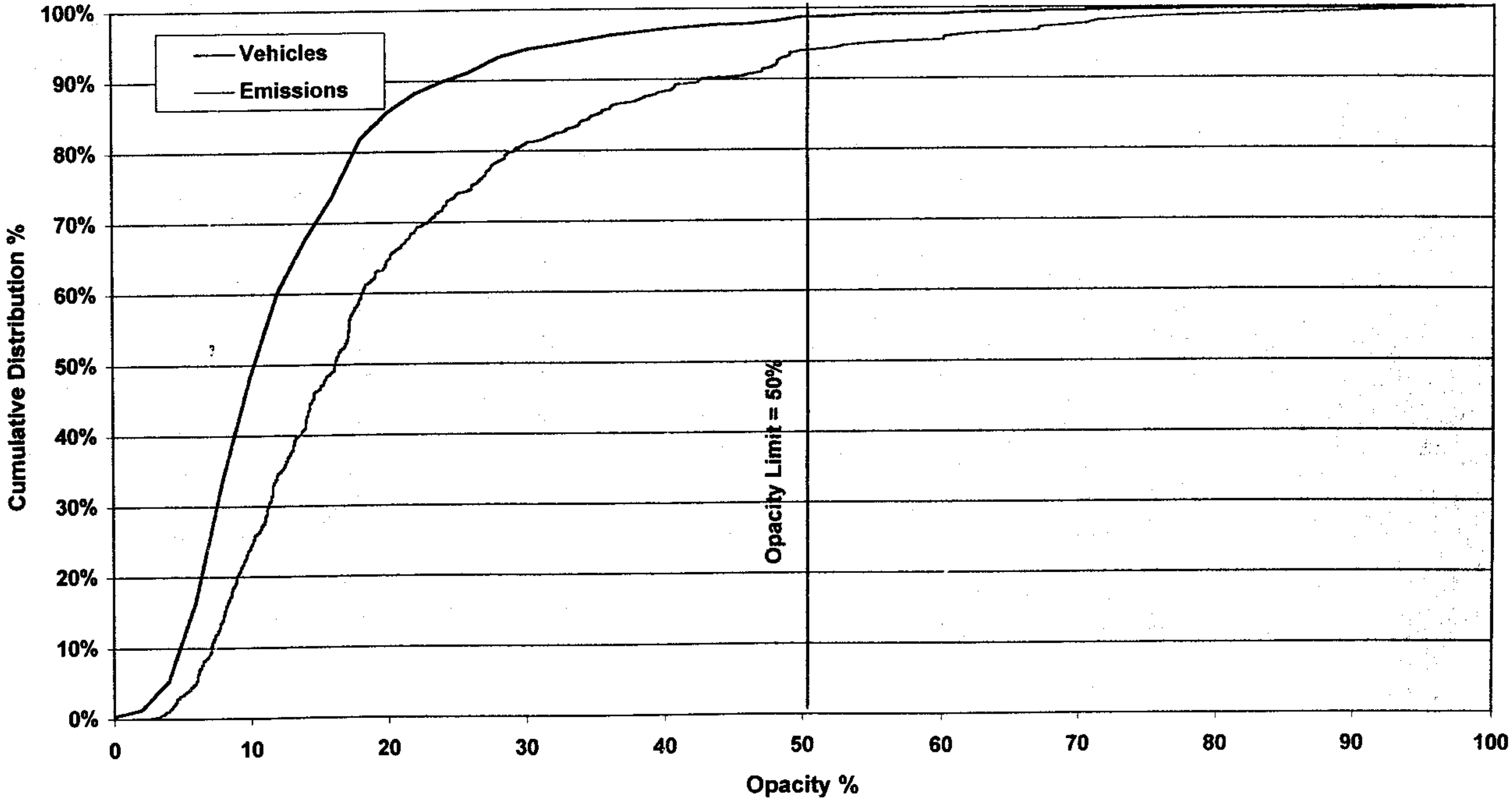


Figure 4.14
Cumulative Distribution of Opacity Readings
Diesel Powered Vehicles Model Years 1995 and After



SECTION 5
CONCLUSIONS, RECOMMENDATIONS, AND NEXT STEPS

5.1 Conclusions

The following are preliminary conclusions reached after studying the results of the on-road-testing and subsequent data analysis:

5.1.1 **Certain makes and types of vehicle are dominant.** If the makes and types of vehicles are not skewed by sampling bias, then conclusions can be reached about which makes and types of vehicles to target in future actions.

5.1.2 **Overall non-compliance rates for gasoline-powered vehicles are between 31% and 39%.** At first glance, these rates appear to be on the high side of normal targets set by other countries and governments standards. It should be reiterated again that the ORT data can not be considered sufficient to adjust emission standards. Adjustment of the standards may be warranted, although this potential action depends on the targets for pollution reduction set by EEAA.

5.1.3 **If enforced, the HC standards for gasoline-powered vehicles would result in approximate reductions in HC of 56% for pre-1995 vehicles and 30% for 1995 and after.** This level of reduction may or may not be acceptable, depending on the targets set by EEAA.

5.1.4 **If enforced, the CO standards for gasoline-powered vehicles would result in approximate reductions of 45% for pre-1995 vehicles and 69% for 1995 and after.** This level of reduction may or may not be acceptable depending on the targets set by EEAA.

5.1.5 **If enforced, the opacity standards for diesel-powered vehicles would result in approximate reduction of only 5-6% for the entire vehicle population tested.** This level is unacceptably low by comparison to any standards set by any governmental in developed countries worldwide.

5.2 Recommendations

5.2.1 **Adjust the sampling technique.** Consider random sampling by using acceptable technique (e.g., random number generator, or by taking every fifth vehicle, regardless of vehicle age, type, model, or make.)

5.2.2 **Enhance the current level of QA/QC for all parts of the program.** Correct deficiencies in data gathering, instrument maintenance and calibration, data entry, data processing, and reporting. Better conclusions could be reached, and better standards setting would result.

5.2.3 **Set future standards based on desired reductions in pollutant levels.** Rather than base standards on what other countries are doing, setting pollution reduction goals and tying them to standards allows the standards to have meaning in Egypt. This report analyzed the data using composite plots of vehicle populations and emissions levels. These plots are one tool that would allow EEAA to select standards for any desired level of pollution reduction.

5.2.4 **Compare the data gathered in the ORT program with that gathered in the vehicle emission testing (VET) program.** The two programs should be complementary, and a comparison of the results could uncover errors in testing, data processing, equipment handling, and other aspects of the two programs.

5.2.5 **Investigate remote sensing technology.** Such technology would offer several advantages. First, it would provide emission data under actual load conditions. Second, it would be less intrusive to the motorist and as such more practical to use for large diesel vehicles such as trucks and buses. Third, it would allow to directly gather mass emission data.

5.3 Next Steps

5.3.1 **Train EEAA personnel to take over the ORT program.** Transfer information about the program and about the data processing so that EEAA can use the program to their optimum benefit.

5.3.2 **Train EEAA personnel in the use of the database.** Educate appropriate people in EEAA on how to use the software, how to manipulate the data to generate results of interest, and how to maintain and enhance the database.